IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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EDITORIALS

THE RELATION BETWEEN TECHNICAL PAPERS AND THE LIFE AND WORK OF OUR ASSOCIATION.

By A. J. STANDING*

As our Organization advances year by year the work of the Association and its Sections falls into new hands, new committees must carry on and we must face the fact that with each succeeding year the work of the Section Papers Committees becomes increasingly difficult both from the standpoint of securing authors and also from the standpoint of deciding on topics of sufficient interest and merit to warrant their being made the subject of papers such as we have come to expect and which will not be in some way a repetition of material now in the records of this Association.

Let us briefly attempt to analyze the place our papers have occupied, are occupying today and will occupy in the future in the life, work, publication, and general status of our particular organization.

Our Association was conceived in the desire of a few Steel Mill Electrical men for that mutual exchange of ideas and information necessary to enable them to more securely establish themselves and their work as an integral part of the operation and personnel of the various Steel Plants that were then beginning to look to the application of electricity as a possible step in the direction of simplifying operation, reducing production costs, and above all in conserving that most valuable of assets, human labor. That their hopes have been realized is amply proven by the rapid growth of Steel Mill electrification just as the growth of our Association has demonstrated the actual value of the early attempts toward the exchange of information and ideas that have so helped the Steel Mill Electrical man obtain the results now accepted as every day practice in Mill operation and at the same time have helped to assure for himself a place of responsibility in the general scheme of Plant organization.

If you will review the list of papers delivered before our Association during the early years of its life you will note that possibly 75 or 80 per cent were presented by the representatives of Manufacturing Companies with the view of describing their particular apparatus partly from an engineering standpoint and partly, of course, from the commercial standpoint. This condition was as it should be at that time because it was to the mutual advantage of all concerned to have such information quickly and directly reach the men who were most interested and who by virtue of their positions were able to constructively criticize and advise the manufacturers in the development of apparatus to be applied to Steel Mill service.

Gradually, as a survey of our Index will reveal, there began to appear more and more papers prepared and delivered by Steel Mill Electrical men touching on their requirements, their operating troubles, discussing the methods used in overcoming them and describing the various points good or bad in connection with the new electrical apparatus entering their Plants, often on a somewhat insecure and experimental basis.

Among the subjects which during the early years of our Association claimed the attention of our Members to the greatest extent, were first the design and adoption of the mill type DC motor for detail applications. This design was arrived at only after considerable discussion during the years 1907 and 1908 and we find that after the mill motor had been finally accepted by the Steel Mill Electrical men there was practically no further discussion throughout a period of several years; but we find that the subject of control, always of parallel interest, has throughout all the years received the continued attention of both active members and manufacturers as evidenced by numbers of papers devoted to some phase of the control problem each year.

The next outstanding subjects we find very logically to have been prime movers and power apparatus of all types, followed closely by the subjects of industrial lighting and materials handling by means of electric cranes.

It was not until 1914 that the subject of Reversing Mill drives and general main Mill electric drives began to occupy the attention of the Industry, but they have been subjects of many interesting papers and discussions each succeeding year.

You will note that the order of these subjects was entirely in keeping with what we know to have been the history of the entrance of electricity into the Steel Industry; starting with the small auxiliary drives and gradually advancing to all auxilliaries and finally to the main drives until then the undisputed territory of the steam engine. Even where the motor has not actually replaced the steam engine the threat of its advance has produced improvements and economics in steam operation not previously thought possible.

The writer from personal knowledge feels that in the handling of the various phases of the general subject of Mill motor drives the proceedings of our Association today offer probably the most sought after and reliable compendium of information from both the Manufacturers' and users' view points that can be obtained. While we do not feel that the sum total of all information on this subject has been realized in them, nevertheless we do feel that the general problems of electric drives have been so handled as to be well beyond the stage of guess and experimentation and we also feel that our records tell the story as it was enacted in the various Plants.

The general subject of Mill drives will continually receive the highest type of engineering attention from the various Electrical Manufacturers in an effort to improve, simplify, and at the same time reduce the cost of their particular type of Mill drive applications. Their efforts will parallel the work of the Mill operating Engineers and will inevitably result in new and better types of drives being developed, installed, and

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*Elec. Supt., Saucon Plant, Bethlehem Steel Co., Bethlehem, Pa.

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The Automatic Blast Furnace*

By FRANK W. CRAMER†

IRON was first used in Western Asia, the birthplace of the human race, and in the northern parts of Africa, which are near Asia. Tubal Cain, who was born in the seventh generation from Adam, is described in the fourth chapter of Genesis, as "an instructor of every artificer in brass and iron." The Egyptians, whose existence as a nation probably dates from the second generation after Noah, and whose civilization is the most ancient of which we have any knowledge, were, at an early period, familiar with the use and manufacture of iron. India also appears to have been acquainted with the manufacture of iron and steel from a very early period. There is a pillar of wrough iron standing near Delhi, India, dating back to the eighth century, before the Christian era, which is about 60 feet long, and probably weighs over 17 tons, showing that they were familiar, at that time, with the manufacture of iron on a large scale, the secrets of which have since been lost. These few statements are made to show that the art of making iron dates back almost to the beginning of history. We might mention the fact that most every nation, during the successive periods of history, was familiar with iron, but even so, no iron implements have ever been found in connection with the ancient civilization in America. In scanning the history of iron making, we find that the real beginning of the blast furnace was about 1340. If we pass on a few more centuries, we find that there were several iron furnaces in America about 1644, and a production record exists that expresses the satisfaction of one manager because his production had reached 8 tons of pig iron per week. Small furnaces, of a similar capacity, existed in many of the colonies, and grew in numbers as time passed on. In the census of 1810, we find that there were 153 Blast Furnaces in the United States, whose production for the year was 53,908 tons. For the next few decades, the number of blast furnaces rapidly increased until, in 1840, there were 804 furnaces in existence, and they produced 286,903 tons of iron during the year. A furnace that could produce four tons of pig iron per day was doing good work at that time.

There is a record in the Iron and Steel bulletin showing that in 1872 the Lucy furnace, of Kloman and Carnegie Brothers, was blown in, and was expected to have the wonderful capacity of 575 tons per week. In 1881, there was one furnace that produced 224 tons in a day. If we scan the reports of 1890, we find that production per furnace had been further increased, and that furnaces then existed whose daily output was 350 tons. During the last thirty years, the size has been further increased, and today we have furnaces whose daily output is close to 700 tons. The story of the growth of pig iron production, in the United States, since 1810, and also the number of furnaces in existence at the different periods, is given in Fig. 1. This brings out the fact that the number of furnaces was a maximum in 1840. The production curve shows the annual output has been rapidly increasing ever since the Civil war period.

This brief historical review has been given to show that, although iron was manufactured in the earliest periods of history, quantity production, and low costs of pig iron have only existed during the last fifty years; in fact, the greatest gains in production per furnace have been made during the last thirty years, which period witnessed the introduction of electrical equipment into the operations.

During these years, the furnaces have grown larger, and competition has become keener, and in those years of business depressions, the manufacturers have endeavored in every way to reduce their

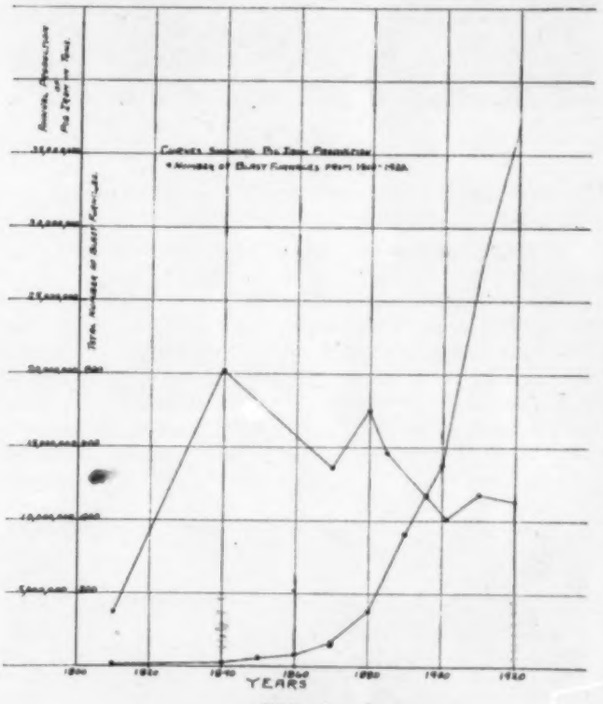

FIG. 1

operating costs. Today, more than ever before, the output of pig iron per man hour of labor employed at the furnace, is receiving closer attention.

The subject of this paper "The Automatic Blast Furnace," indicates that we are approaching the minimum possible number of men necessary to operate a furnace, and when this minimum is reached, that any further reduction in man hours per ton will be done by increasing the size of the furnace.

At this particular plant, the reduction in operating force goes back to the raw materials. The steam engine brings the cars loaded with ore and stone to the "ore field," and places them on the traveling dumper, which revolves the cars, and deposits the material in the field where it is picked up by ore bridges that distribute it for storage. We might pause a moment and note that one of these bridges

*Presented at Pittsburgh, Pa., April 18, 1925

†Asst. to Elec. Supt., Bethlehem Steel Co., Johnstown, Pa.

has the bridge motion control in the trolley cab. Such construction is usually objectionable on account of the large number of additional bars necessary to place on the bridge girders to control this motion. We surmounted this difficulty by using polarized relays for controlling the direction of travel, and are able to operate the bridge motion with only one additional bar. Such a scheme enables the bridge to handle a greater tonnage per day than one where

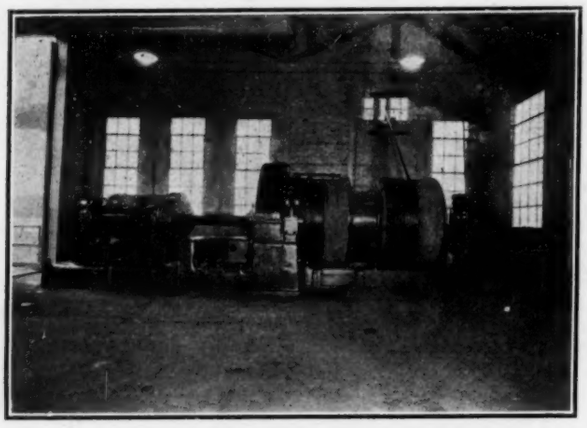

FIG. 2

the operator must go to another control house each time he wishes to move the bridge.

The ore and stone remain in the field until required for filling purposes, at which time they are loaded on Hoover and Mason transfer cars by the bridge, and conveyed to the stock bins. These cars, with one operator each, have replaced the steam engines and train crews that formerly did this work. They also convey the coke to the furnace from bins located over the track. At this particular installation, the coke, after being quenched and screened, is transferred to these bins by means of belts that

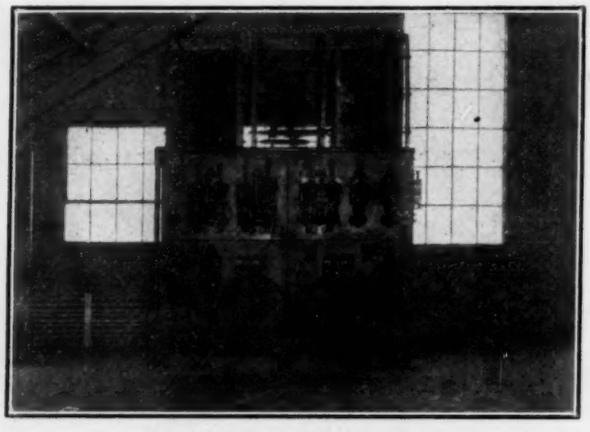

FIG. 3

eliminate all human labor. From these few operations, it can be seen that the man hours per ton of charge have been considerably reduced in getting the material accessible for the charging. Having the material in the stock bins accessible to the scale cars, we can consider the operations at the furnace.

By means of modern tapping devices, mud guns, etc., the number of men at the front of the blast furnace has been steadily reduced. Similarly, in the stock house, by means of modern bins, scale cars, skip hoists, etc., the number of men required to charge a furnace has been reduced to two or three men. Realizing that there was a possibility of still further reduction in the number of men on the charging side, we have worked out, and put into operation, a one man charging arrangement. Even overlooking the saving in labor, the advantages of such an arrangement are obvious.

Getting material from the bins into the furnace in proper sequence, at proper times and in proper condition, requires the services of at least semi-skilled labor, and also the hearty co-operation of men of great trustworthiness. No superintendent can spend all of his time in the stock house checking the charging of his furnace, and even if every precaution is taken in the matter of records, it is entirely possible for the stock house men to do differently than the records indicate. If this responsibility of properly stocking the furnace rests with one man instead of being shared by three men, the advantages are easily seen.

The main units entering into charging from the bins to the furnace are the scale car, skip car, dis-

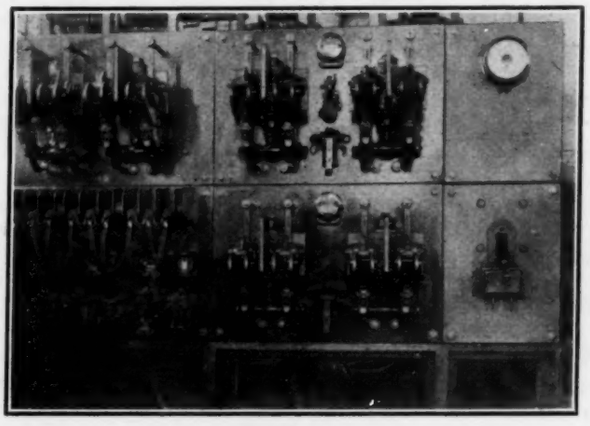

FIG. 4

tributor bells, and test rod. These ordinarily require the services of not less than two men—a scale car operator who collects and weighs the ore, stone, and in some cases the coke, and deliveres them to the skip car—and a skip operator who controls the hoisting, operates the bells, and test rod mechanism, and who is also required to make necessary records as to number of charges, time of completion of each charge, and stock line level at certain intervals. Considering the possiblity of reducing the labor herein involved, it is apparent that the scale car operator is almost indispensable, for the material must be weighed and charged in certain cycles, which vary from time to time. Hence, the skip operator is the man who could possibly be dispensed with. By the use of electric drives and interlocks, his work has been lessened to such an extent that, with a few more automatic devices added, his duties could be dispensed with, and the scale car operator could perform all the duties of charging.

At this particular furnace, the scale car is a Hoover and Mason two-compartment car. Running this car underneath the proper bin, the operator

pulls a lever which connects the motor operated shaft to the drum, and enables the charge to fall into the car. When the scales indicate the proper weight of material, he releases the lever and closes the gate. He then fills the second compartment of the car in a similar manner. Having done this, he runs the car back over the skip pit, drops the material in the bucket, and throws the master controller that sets the hoist in motion, and the skip bucket takes its load to the top of the furnace.

Motor operated skip hoists are among the modern developments of furnace operation, dating back not more than twenty-five years, and have proven to be a necessity as well as an economy on the larger furnaces. The time of travel can be accurately set and ideal starting and stopping conditions established. The ease with which they can be interlocked with other operations has been of great aid in reducing the labor necessary to operate a furnace.

We have several types of motor driven skip hoists in operation, including a single bucket counterweighted hoist. The control on this is so arranged that the operator presses a button, the car goes to the top, dumps, and returns automatically. By the

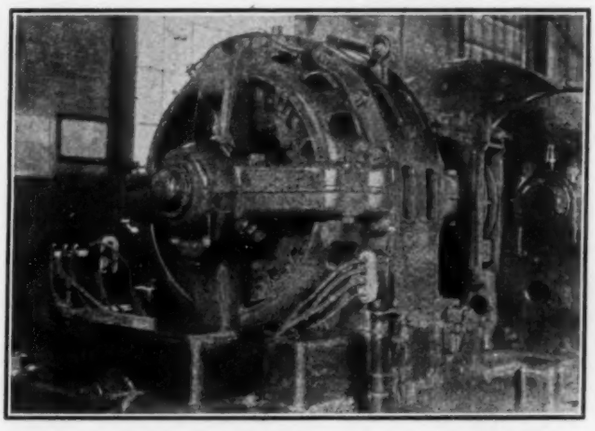

FIG. 5

use of this control, the time saved with automatic dumping and lowering, over the old method (when this hoist was steam driven and the time interval was left to human judgment) amounts to several hours a day. There are, also, two A.C. motor driven hoists that have been in operation several years. These motors have two windings on the stator, which give the hoist acceleration and decelleration characteristics similar to those of D.C. motors using resistance and armature shunts. These A.C. drives have many advantages, especially if there is not a supply of direct current available, and will show a smaller KWH per ton of material hoisted, due to the fact that the transformer losses are always less than those of converting machines.

After the skip hoist has operated, the material is deposited on the small bell. When this has been done, the next automatic device, known as the McKee Distributor, functions.

It consists of a cylindrical hopper, so mounted on ball races as to be rotatable, and with it revolve the small bell and bell rod, the latter being suspended from a small ball race. The outer circumference of the upper part of the large ball race, carrying the revolving hopper, consists of a gear which engages a pinion driven by a 10 HP motor through a flexible coupling, and a worm reduction. The entire driving unit is carried on the steel casting, which supports the ball race called the spider. Thus the driving unit and revolving unit are integral with very little chance for misalignment, and consequent wear, and the gear reduction is totally enclosed, and running in oil. No space is taken up on the furnace

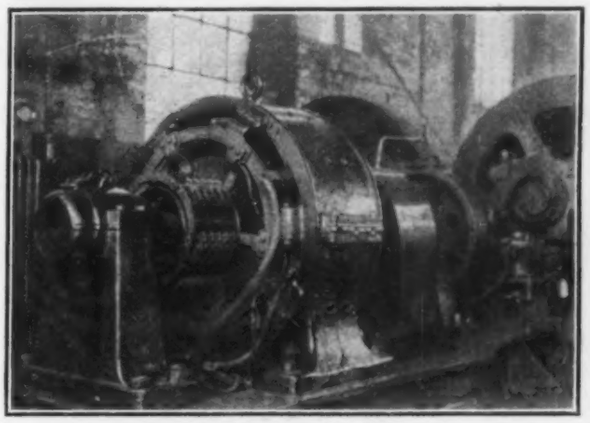

FIG. 6

platform for driving mechanism, and the drive unit can be placed at any point around the gas seal. The limit switch, controlling the degree of rotation of the top, is driven direct from the vertical shaft carrying the main driving pinion. The main control board is located in the hoist room. A light panel in the stock house shows what angle of rotation the distributor is making, and also indicates when the motor is running. The entire construction of top and control mechanism is simple, rugged, and fool-proof. It is designed to distribute the error in the distribution of ore, stone, and coke, as they fall

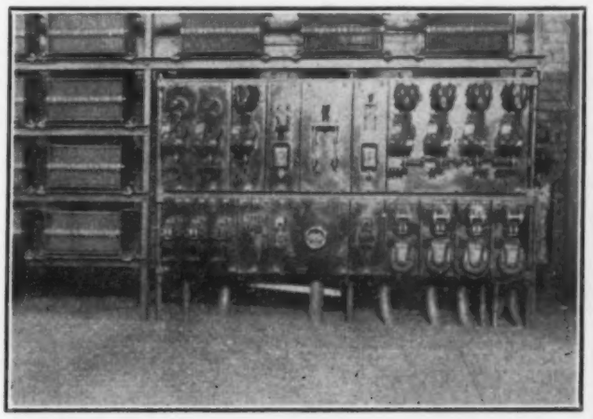

FIG. 7

from the skip car onto the small bell, since, in this operation, the large pieces falling first go to the far side of the bell, while the fine pieces are deposited on the near side. When the material is placed in the furnace, without correcting this condition, the lumps and fines are not evenly distributed in the furnace, and result in a potent cause of channeled linings, irregular working, and other evils. When a

revolving top is used, this condition is remedied by distributing the material over the periphery of the large bell, which is done by turning the skip load of material, on the small bell, through successive angles of rotation for successive charges. This even distribution of material, throughout the cross section of the furnace, results in lower coke consumption, higher production, more regular product as to quality, easier control of furnace, longer life of linings, and lower operating costs.

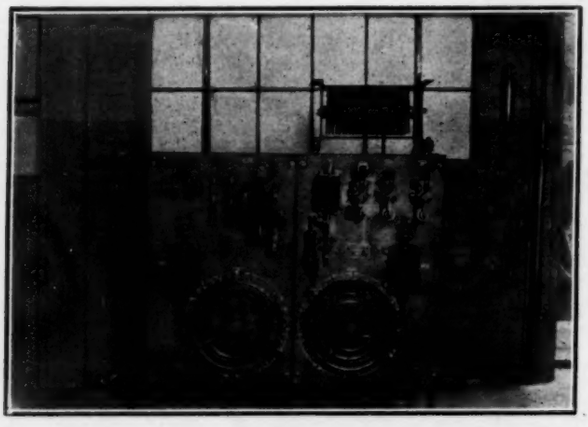

FIG. 8

Our particular cycle of operation with the distributor is as follows: The first six skips, or the first charge, is dumped from the small bell on to the large bell without the top revolving. Then the big bell dumps this charge into the furnace. When each skip of the second charge is dumped on the small bell, the top revolves 60° or 1/6 of a revolution before the material is dumped on the large bell. Hence, the position of the lumps on the second charge has been advanced 60° on the periphery of the large bell from those of the first round, and they will occupy a similar position in the furnace. On the third charge of six skip loads, each load, after being placed in the small bell, is revolved 120° or 2/6 of a revolution before being dropped on the large bell, and then into the furnace. On the fourth charge, each skip load is revolved 180° before being dropped on the large bell. On the fifth charge, each skip is revolved 240°, and on the sxith charge, each skip is revolved 300°. This completes one round of six charges or thirty-six skip loads which have been deposited, so that the lumps and fines have been dropped from six different point on to the large bell, and a uniform distribution of material has been obtained.

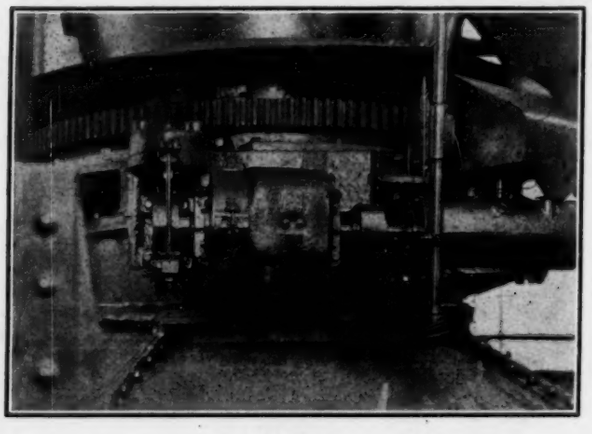

FIG. 9

The driving mechanism for the distributor is so interlocked with the skip hoist motor or engine that the motor is automatically started as soon as a skip load of material is placed on the small bell. After the small bell is turned through its proper angle of rotation, the limit switch, geared to the driving units, opens the motor control circuit, the brake is set, and the control system for the small bell mechanism is energized, causing the small bell to be lowered. It is essential that the small bell be kept closed while rotating, for, otherwise, the material is not turned to its proper position.

Having described the revolving top, the next operation is the functioning of the bell mechanisms. There are several methods of operating bell hoists on blast furnaces, the most common way being by means of cylinders attached either directly, or through a cable to the bell beams. These cylinders are usually actuated either by steam or air, and in a few cases oil is used. On several of the modern furnaces, the operation is accomplished by means of a motor driven mechanism with automatic control. There are many advantages in favor of this electric operation, such as the lower power costs, the perfect control of the operation as to speed, and the assurance of that all-important factor in blast furnace operation—uniformity. It also makes the operation independent of the human element, insuring against bells being opened at the wrong moment in the cycle of operations, especially when charging the furnace, and further, is a step forward towards a smaller number of men employed for filling purposes.

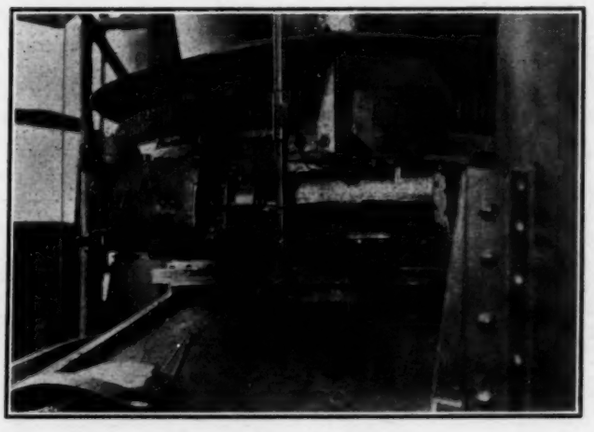

FIG. 10

Electrically operated bells have been in use for several years—the first ones being made by the Otis Elevator Company, and installed at the Detroit Iron and Steel Company, the Pittsburgh Steel Company, Edgar Thompson Works of the Carnegie Steel Company, and several other places. All these early bell hoists were of the crank type. With this arrangement, the bell is suspended from one end of a pivoted lever, which is supported by the furnace top. A heavy counterweight is fastened to the opposite end

of the lever. The amount of counterweight must be sufficient to overbalance the weight of bell, bell rod, and maximum charge, by from 5,000 to 10,000 lbs., in order to make a seal between the bell and the hopper.

A rope is used for connecting the bell lever to the crank pin of the machine. The bell is opened by turning the crank through one-half of a revolution, which raises the counterweighted end of the bell lever. The load on the machine, while the bell is being opened with a full charge, varies from minimum at the start to maximum at the end of the stroke when the bell is empty.

The bell is closed by turning the crank through the remaining half of its revolution, which allows the counterweighted end of the bell lever to drop. Throughout the closing stroke, the machine is subjected to a generator load, equal to the maximum motor load, which occurs at the end of the opening stroke. The maximum motor load also occurs throughout the opening stroke of an empty bell, and the machine must be designed for this condition.

The throw of the crank must equal the travel of the rope at the point where it is attached to the bell

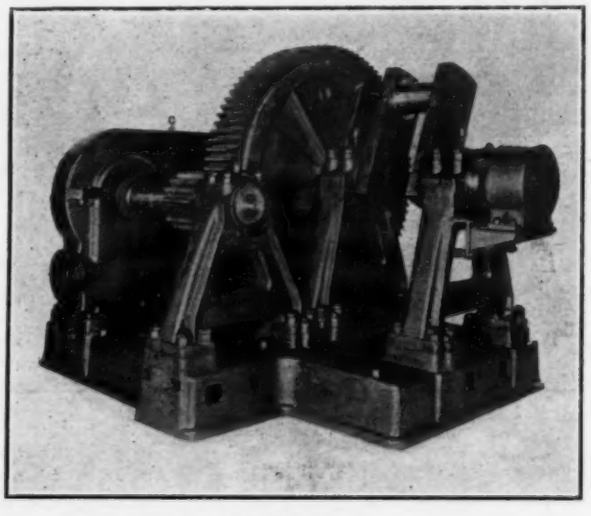

FIG. 11

lever, plus the allowance necessary to make for rope stretch and rope sag. One of the disadvantages, which results from using a crank type machine with the roping and a counterweight arrangement, just described, is that the travel of the bell cannot be altered because it depends on the motion of a crank having a fixed radius.

The Otis Elevator Company has recently developed a new type of furnace hoist that makes use of a standard reversible elevator drum machine, with a comparatively small amount of counterweight on the bell lever. This arrangement overcomes the numerous undesirable features of the crank type machine. To accomplish this result, the pivoted bell lever is used with a counterweight sufficient only to balance about 4/5 of the weight of empty bell and bell rod. A separate counterweight located on the ground or on a structure near the ground acts as a sealing weight.

With the bell closed, the sealing weight is just slightly raised off of its support. It is effective for the purpose of obtaining a definite sealing pressure only when in this position.

Before the bell starts to open, the machine is operated so that the rope unwinds, letting the sealing weight down on its support. As soon as this weight is down, the continued unwinding of the rope causes the bell to open, because the amount of weight on the bell side is greater than on the counterweighted side

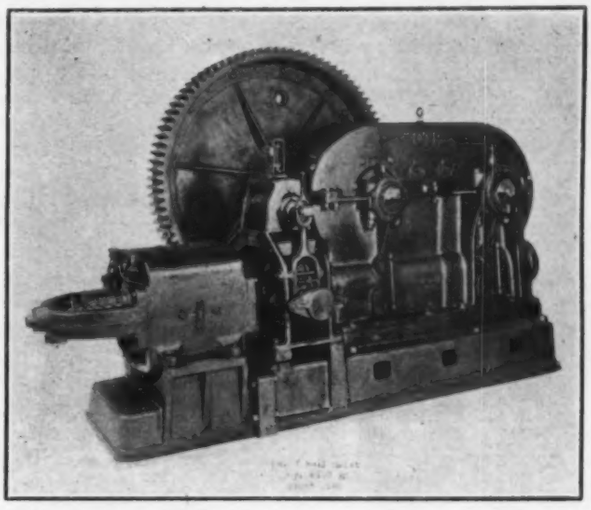

FIG. 12

of the bell lever fulcrum. The amount of counterweight on the bell lever must always be less than the corresponding effect of the weight of empty bell and rod, in order to obtain an overbalance on the bell side and open an empty bell. Opening the bell places a generator load on the machine which varies from maximum when the bell starts to minimum at the end of the stroke when the charge is dumped. The bell is closed by operating the machine in the reverse direction thereby winding up the rope and pulling

FIG. 13

the counterweighted end of the bell lever down. During this operation, the sealing weight remains on its support, because it is greater than the pull required to close the bell. This weight does not move until the bell seats against the hopper, when the continued winding up of the rope lifts the sealing weight off of its support. Immediately, the weight strikes a limit switch and opens its contact, which

results in stopping the machine. This arrangement makes certain that the bell will always seat against the hopper with full sealing pressure independent of rope stretch and rope sag. The sealing weight is provided with a spring hitch designed to absorb any shock which may occur when the weight is picked up.

In addition to the Otis Bell Rig, there have been several installations of the Proudfoot-Harry Rig, which consists of a horizontal steel screw and bronze nut driven by a 15-25 HP compound wound motor—depending on size of charge—through suitable gear reduction. From the end of the screw, cables lead over sheaves, which are mounted integral with the hoist to an equalizer, and thence to the top of the furnace to the bell beam. The screw is moved back and forth through the rotation of the bronze nut to open and close the bell. Dynamic braking and automatic reversing are provided. The limit and reversing switches are actuated by a traveling arm, attached to the screw, which operates through a shipper arm as shown. Safety cut out switches, in case of over travel, are also provided. The screw, bronze nut, and gears are totally enclosed, running in oil. With this type of bell rig, the motor, in opening the bell, only supplies power to raise the weight differential between the counterweight and the weight of the bell and bell rod plus the charge. The travel of the bell is easily adjusted by moving the position of the limit switches along the shipper arm. Should a lump of ore or stone prevent the bell from closing, the counterweight, which seals the bell, is exerting the pressure, and the motor will be stopped when the shipper arm travels the usual distance showing

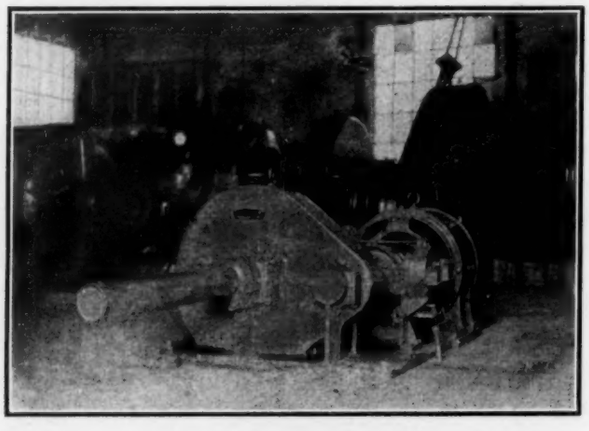

FIG. 14

a slack rope condition. Another feature of this type of hoist is that, should the hoisting rope break or fail, the bell will remain sealed.

Morrison Bell Rig:

The Morrison bell operating rig consists of a rope leading directly from the end of the bell beam to an equalizer, two ropes leading from the equalizer to pins on the end of levers fulcrumed on either side of a large gear, but connected to the gear through a spring barrel trunnion, the spring being compressed when the bell is seated. The gear is actuated by a 10 HP motor, through an efficient worm gear reduction and pinion. When the current is turned on the motor, the brake on the motor shaft releases, the large gear makes about one revolution, the bell lowers and raises, and when the spring between the levers and gear has been compressed sufficiently to give the desired sealing pressure between the bell and hopper, the geared limit switch stops the motor and sets the brake. The motor is reversed for the next cycle of bell. A torque limit relay and overload switch stops the motor, in case the geared limit switch fails to function, or a piece of scrap becomes lodged between the bell and the hopper. Practically no current is used except for the fraction of a second when the bell seats, and the spring is compressed, as the burden and unbalanced weight of the bell overhaul the motor while the bell is lowered.

On any of these types of bell rigs, a controller can be furnished with switches, which provide for

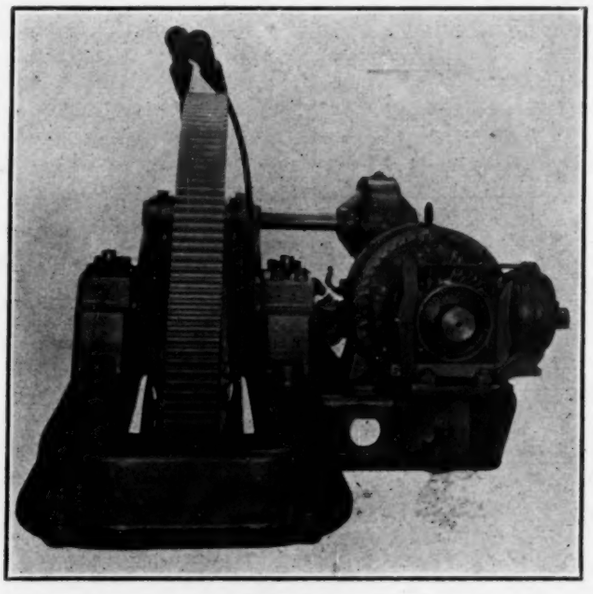

FIG. 15

opening and closing the bell independently of the automatic operation. Each controller is electrically interlocked so that only one bell can be operated at a time. One or more extra skip loads can be added to the furnace burden without affecting the automatic arrangement, and without altering the sequence.

At this time, we will briefly enter into the advantages of electrical operation of the furnace bells over the older method of operating with steam, air, or oil, actuated cylinders.

A series of tests conducted at different furnaces, using steam cylinders for bell operation, reveals that an average steam consumption for a modern capacity blast furnace runs close to 40 B.H.P. A considerable part of this consumption is due to condensation. At those installations where cylinders are actuated by compressed air or oil, the items of steam condensation, and of necessary bleeding of steam lines in cold weather, are of course, considerable less than in the direct application of steam, and the power consumption expressed in B.H.P. somewhat lower for air and oil operated rigs.

In order that we might have available some data concerning the power consumption of the electric

bell rigs, and also for the revolving top, we placed accurately calibrated Sangamo Watthour meters in the circuit of each drive at one of the furnaces. For a period of thirty days, a log sheet was kept with daily readings of power consumption, and also furnace filling data. In order to arrive at a good average figure, the data secured during the month was compiled, and averages taken. The results of this test are given in the following table:

Number of times small bell operated	20,088
Number of times large bell operated	3,348
KWH consumed by small bell	1,047
KWH consumed by large bell	538
KWH consumed by revolving top	301
KWH consumed by each operation of small bell	.0521
KWH consumed by each operation of large bell	.1606
Total weight in tons of material charged into furnace	59,016
KWH consumed by small bell per ton of charge	.0177
KWH consumed by large bell per ton of charge	.0091
KWH consumed by revolving top per ton of charge	.0051
Total KWH consumed by bells and top per ton of charge	.0319

During this test, the following weights of material were used per charge:

2 Buckets of Ore.....11500# per bucket
3 Buckets of Coke..... 3500# per bucket
1 Bucket of Limestone..... 5300# per bucket

So far as we could find, power consumption on electric bells and tops had never been accurately determined, and these results were rather surprising. Summing them up, they show that the total power costs per month, on a 600-ton furnace, for electric

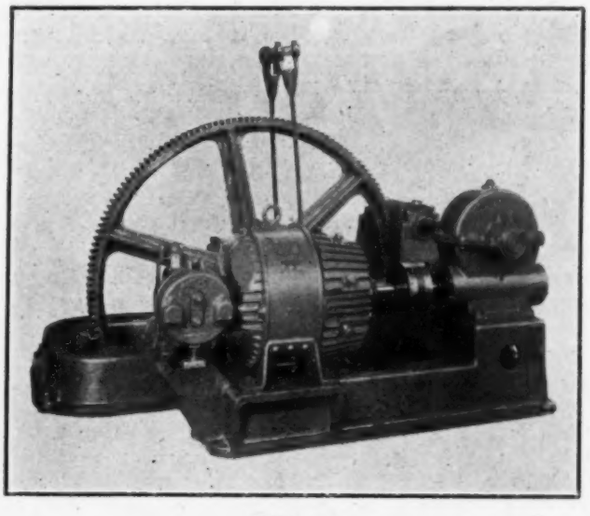

FIG. 16

bells and a revolving top, are less than $20.00, with power at 1c per KWH. When this cost is compared with that of a steam operated rig, the large savings on monthly power costs per furnace is seen. In addition to this savings, the cost of upkeep and repairs is practically nothing.

The steam operated rig, in addition to the high steam cost, has numerous other disadvantages, such as a high maintenance cost, unevenness of operation, difficulty of keeping the cushioning effect adjusted to avoid slamming of the bell, and what is probably the most serious trouble, with condensation and consequent freezing in cold weather. On the other hand, it is a simple direct method of fairly low first cost. The various types of oil and air operated bell rigs are much more cumbersome and expensive to install and maintain, and have many of the objectionable features of the steam rig, as far as difficulty of keeping in adjustment is concerned.

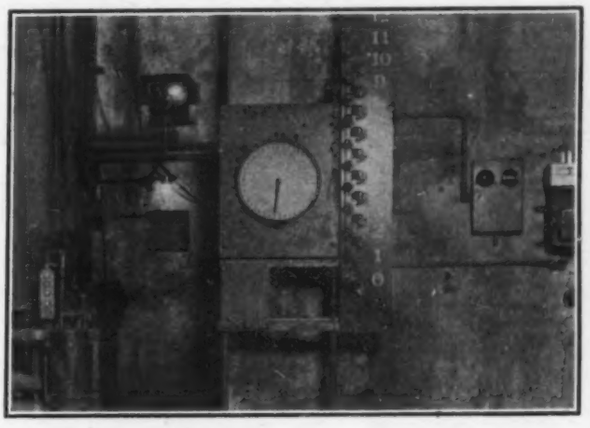

FIG. 17

The advantages of electric operation on the bell mechanism are obvious; the power efficiency is much greater, the upkeep and maintenance much less, the operation of the bell is absolutely uniform, safety arrangements more positive, speed of operating cycle greater, and finer adjustments can be secured.

Once the operating conditions, or operating cycles of the furnace have been established, it is important that nothing interferes with, or disturbs them. This is particularly true of the charging operation, and the fact that the material leaves the bell at a uniform rate, round after round, means that its distribution in the furnace is less disturbed than in the case of steam or air operation, when the cushioning adjustment is not functioning properly.

The electric rig lends itself readily to automatic interlocking with the other operations in charging the furnace, and aids in making it possible to entirely remove the human element and its possibilities of error. For these reasons, the electric bell hoist, both on account of its adaptability to automatic operation, and also to the increased speed with which it permits charging to be accomplished, is becoming indispensable to the modern furnace. In the case of steam or air, for every complete operation of either bell, the skip man or operator must perform two operations, one to lower, and the other to close the bell. With the electric rig, interlocking and automatic, no manual labor is required.

Location of these bell rigs can be made, either on top of the furnace, or preferably in the hoist house. Connection between the rigs and the bell beams, when the latter of the above mentioned locations is chosen, can be made either by steel cables or probably preferably through steel rods. An in-

terlock can be, and is generally provided, between the large and small bell rigs, so as to prevent their being opened at the same time, and also for their automatic operation in the proper order of the charging cycle. An independent movement of either or both bells is possible at all times by means of an extra controller or push button.

We now have left one important function in operation—the gauging—which tells the story of the furnace condition. Up to the present time, this has been up to the operator, and if he is untrustworthy, the records can easily be altered without much chance of his being detected. Should trouble develop on the furnace ten or twelve hours after he has made a "rush" fill, he alone knows the cause. To remedy this condition, and give the Superintendent an automatic graphic record of gauging, was the final step in the one man charging arrangement.

In the development of the automatic gauging device, one of the first pieces of equipment sought for was a simple, yet accurate, timing device. This was found in the "Repeating Process Instrument" made by the Stromberg Clock Company. This interesting device has a small induction motor running in oil as the timing element. This motor runs with the frequency of the power system, so that its accuracy is the accuracy of the line frequency. The type we

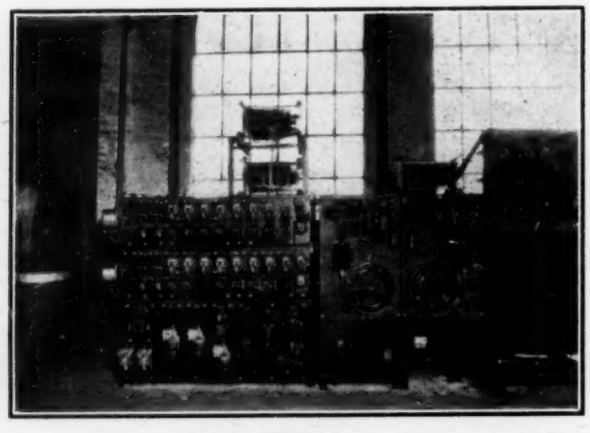

FIG. 18

purchased can be set to make contact at any interval up to twelve minutes. On this particular installation, the clock is set to make contact every five (5) minutes, which means that the gauge rod mechanism will operate at intervals of five (5) minutes, unless the large bell happens to be open, when the interlocks will prevent it from functioning. When this clock closes its contact, a relay is energized that causes the automatic control on the motor driven rod mechanism to function.

This operating mechanism then lowers the gauging rod until it touches the stock in the furnace. When it does this, the weight of the rod no longer exerts a pressure on the slip drum of the machine. This causes the slip drum to grip the inner drum, which closes contacts that reverse the motor, and the rod is hoisted out of the furnace. This gauging operation is very rapid, not requiring more than three (3) seconds for maximum travel. The rod is lifted clear of the large bell after each gauging.

Having developed an automatic gauging rod, the next step was to record the gauging. If this could be done, the furnace Superintendent would have a record of the height of his stock in the furnace at all times. In fact, if he so desired, it is an easy matter to install long distance reading meters that would record this in his office.

After a conference with the Blast Furnace operators, it was decided that, in our case, the maximum distance to be gauged from a full furnace to a low furnace was twenty (20) ft. Should the stock be below this twenty-foot level, the rod will record only twenty (20) ft., being automatically reversed at this point, and brought back without touching the stock. The travel of the rod can be recorded by several methods. At the present time, we are experiment with both a hydraulic pressure device, and a voltmeter.

Having developed this automatic gauging device, we were almost ready to put into operation the one man charging arrangement. All that remained was to give the scale car man some sort of a visual picture of what was going on. This was taken care of in the following manner:

A large dial was devised to operate from the bell movements. You will note from the picture that it is divided into six groups of numbers from 1 to 6, and another series of numbers at the end of each set of six, running from 1 to 6. The meaning of these is as follows: Each group of six denotes the movements of the small bell, and also shows the angle in which the distributor is working. The other series shows the movement of the large bell, so that the scale car operator knows, at a glance, which skip car of a particular round he has placed on the small bell, that this bell has revolved, and whether or not the large bell has operated.

In addition to this, we added a system of gauging lights operated from the rod that shows the condition of the stock at the last gauging. Opposite each light is a number showing the distance in feet the stock is from the top of the furnace. Thus, at a glance, the operator can tell the condition of the stock, and also whether all the automatic devices are working.

We can now record the summary of the whole operation of the one man charging arrangement. The sale car man fills his car from the proper bin, and deposits the material in the skip bucket. He then throws the master controller to the "on" position. Should the furnace be full, the lockout on the gauging device will prevent the skip from rising. He can check this condition by a glance at the gauging board. The skip load will remain at the bottom, and if he does not throw the master back to neutral, the load will travel to the top after the gauging rod has found there is room for more charge. In addition to this, an alarm can be installed that will function when there is low stock in the furnace. If the furnace is not full, the skip bucket will automatically go to the top, and dump its charge into the small bell hopper. When it does this, the limit switch, operated by the hoist, closes the master control for the McKee Distributor, which automatically revolves the charge through the proper angle. When this movement is completed, the master circuit to the small bell is closed, and this bell operates. If it is

the end of a charge, the sequence switch closes a circuit on the large bell which causes it to operate. It is impossible to operate both the large and small bells at one time. All of these movements have timing relays so that the time necessary for them to operate properly can be adjusted. Also, each has a cut out switch that enables the scale car operator to cut out any function, or add an extra operation at any time without interfering with the interlocking arrangement.

After the large bell has operated, the interlocking functions have been completed with one exception. The gauge rod functions every five (5) minutes. It did not seem advisable, however, to operate the gauge rod when the large bell was functioning, so in case this ever happens, the control circuits are so wired, that if a gauging time comes when the large bell is open, the rod will not function, but if the time for dropping a large bell should coincide with the gauging time, the large bell would wait (not more than three seconds) until the rod was up, and then proceed to drop its load. The wiring of this system might seem complicated from this brief description, but in reality, the control boards are of a type all mill electricians are familiar with, and the interlocking is very simple: just a case of the completion of one operation closing the control circuit for the next one.

There are many advantages in the one man charging arrangement. Indicating recorders can be arranged to show in detail the different operations so that the chart of one day's operation is almost the same to a furnace superintendent as if he were personally present in the stock house all of the time. Given the output of any furnace, and the materials involved, the entire operation can be worked on a detailed schedule, component parts of which are the time taken by the travel of the skip and the operation of the distributor, and large and small bells.

With furnaces being designed for larger and larger outputs, the element of time consumed by each operation is very important. It is necessary to keep the number of operations entering into the charging of a furnace at a minimum, and this can only be accomplished by increasing the size of units handled. There is a marked tendency towards these larger units, such as scale and skip cars, as the size of the furnace increases. The question of distribution becomes more difficult, and an arrangement that assures proper distribution regardless of size of charging unit is one of the leading factors in making one man charging a success.

Since electrical operation of these parts guarantees absolute uniformity, so far as the time element is involved, it is entirely possible to set a fixed schedule and follow it out. Automatic stock line recording, as a part of these operations, gives a complete record of the conditions at the top of the furnace.

Thus, we have accomplished the complete electrical control of charging, and put into operation a one man charging arrangement, which has not only reduced the human labor required, but, what is more important, has supplanted uncertain and untrustworthy labor with man's most certain and trustworthy tool-electricity.

DISCUSSION

A. C. Cummins*: The paper which was presented this afternoon is quite closely related to a subject that has been discussed by nearly every one engaged in the manufacture of steel, namely, the reduction of the cost of producing pig iron. A number of reasons have been ascribed to the great interest taken in reducing blast furnace costs during recent years. One of which is the fact that European pig iron has been delivered at our seaboard markets at a price lower than would allow a profit if produced by our own furnaces. Of course this is largely a matter of monetary exchange rates and is not an indication of the relative production efficiencies of Europe and America, but still I think it can be said that it is partly responsible for arousing interest in the subject of blast furnace efficiency. It is also true that President Coolidge and Herbert Hoover have expressed themselves quite forcibly on the subject of improving general industrial efficiency throughout America, and comments on the subject by such prominent persons cannot help but arouse general discussion. Within the circle of officials engaged in pig iron and steel production, the feature that has been particularly discussed is that of reducing labor costs. Any means that can be devised to reduce labor, and increase the regularity of blast furnace operations should be of particular interest to blast furnace operators, whether such reduction in labor cost and improvement in operation is secured by mechanical, electrical or metallurgical improvements. The paper presented by Mr. Cramer this afternoon treats specifically the improvements in equipment for delivering raw materials from the blast furnace stockyards to the furnace. It saves labor and should improve the regularity of operation, and I believe will prove unusually interesting to the members of our Association and their guests who are here today.

I see the matter of having suitable men to tend the maintenance of blast furnace equipment attracts considerable attention. I believe one cause that has contributed to poor maintenance in many plants is the fact that many different varieties of electrical equipment have been installed at the different individual furnaces. As a result the maintenance men must be familiar with the operation of several different styles of apparatus and thus the difficulty in procuring suitable men for the position is greatly increased. During the past two years at Duquesne, we have made quite a number of changes in the furnace equipment with the idea of standardizing the types of circuit used for auxiliary control equipment as well as the motor and hoist equipment. As a result we are able to maintain the electrical equipment which handles the raw material from the bins to the furnaces with only one maintenance man per turn. Of course when any large replacements are made it is necessary to give this man help. It is my opinion that if we had not attempted to standardize our equipment that at least two men per turn would have been required.

Some one has said that the elimination of a man justfies an investment of $25,000. We didn't spend that much.

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*Elec. Supt., Carnegie Steel Co., Duquesne, Pa.

Barton R. Shover:* Our president expressed the truth when he said this was one of the most interesting papers that has ever been presented before the Association. It marks another milestone in that long, hard, uphill road toward the complete electrification of the industry in which we are all so vitally interested. It also shows how long it sometimes takes to get things done and to have the electrician's ideas adopted by the operating men, who naturally hesitate about changing from methods which are fairly satisfactory to something undeveloped.

The automatic operation of blast furnace charging apparatus dates back about 20 years, when the Ohio Works of the Carnegie Steel Company was getting ready to put in Nos. 5 and 6 Blast furnaces. Those furnaces were equipped with automatic control on the skip, revolving top, large and small bell, and distributor, and the equipment is still operating satisfactorily. It was so designed that the operation of the skip started everything, and like the installation that has been described today, there was a fixed sequence to the operations of the various pieces of apparatus; they could not open both bells at one time, the skip could not go up until after the small bell had closed, etc. Within the next few years there were three more installations made, but if there were any more put in, no royalties were paid to the owners of the patents. It is to be hoped that it will not take 20 years to prove the advantages of many other things that have been started in the industry in the application of electricity, for there is no valid reason why operating and financial men should not take advantage of many of these things in less time than they do.

There are one or two points in the installation described today that seemed to offer some objections. Although to the novice this apparatus may seem complicated, it is no more so than a regiment is more complicated than a company. Another possible objection is the question of safety Is it safe to leave one man alone in the stock pits where many things might happen which would be dangerous to him or to the whole plant? There is also the ability of one scale car to handle the entire charge of ore, stone and coke for a modern furnace where capacities are now over 700 tons daily, and before long may be over 800 tons. If there are not too many kinds of ore used it might be possible, but in some instances there would be a question and if two scale cars are required, no labor would be saved.

Blast furnaces work better where all operations are regular, and since nothing can be more dependable, nothing produce greater regularity than automatic control such as has been described here, it is perfectly conceivable that the net results might pay good returns on the investment required to install an equipment, even if no labor saving were accomplished.

A. E. Maccoun:† I enjoyed listening to this interesting paper, as I have gone through most of the developments of this work myself, not only as a blast furnace operator, but also having originally been an electrical engineer; and I would like to say this about the blast furnace operator,—that I do not know of any operating position that requires more knowledge of electrical, mechanical and chemical engineering, and I do not think that the blast furnace operator at the present time is of very much account unless he has this rather broad knowledge. Most of our blast furnace operators have a general knowledge of all these subjects, and nearly all of them that I know have an extensive knowledge along these lines.

Regarding the present development, we are not quite as far behind the times as most of you, who are not familiar with the subject, might think. In the first place, the first electrical skip hoist was operated at Edgar Thomson in 1898, and it worked successfully. I happened to develop this hoist and I disposed of the rights to the Otis Elevator Company, which they acquired. Later on, in South Chicago, Mr. Clark designed another hoist, along somewhat similar lines, which I think was disposed of to the Cutler-Hammer Company; and later on, I think Mr. Shover, at the Ohio Works of the Carnegie Steel Company, had something to do with developing the electrical bell operating device which was also licensed by the Otis Elevator Company, following which the hoist and bell operating device were put in sequence. Later on, Mr. McKee developed the McKee top and that was added in sequence with the electrical hoist and bell operating rig. Many plants have been running with these devices for over fifteen years and doing very well; and the last thing that has been developed is the stock recorder referred to in this paper. I am not very familiar with that, but if it is a good thing and proves to be of value, it will probably be added to the balance of the equipment which has proven successful for many years. But the point I wish you to note is that all modern blast furnaces are equipped with all of this equipment that has been described, and have been equipped with it for over ten years, and the only thing that is lacking is the automatic try rod. We all have try rods, and many of us have used automatic devices with recorders attached. Whether this new try rod will prove satisfactory will be determined by experience, which is the only way to determine these things.

The main feature brought out by this paper was that this arrangement is a one-man proposition. I know it is not actually a one-man proposition. At Cambria they have to use a "poker," or bin man, as in other Hoover & Mason stock yards, as well as the car operator—so that makes two men. One man can look after the other to a certain extent, which answers Mr. Shover's objection. Also, I might say that five or six years ago, Mr. Mathesius of South Chicago Works was running with only a larry man and a bin man, but later I believe he changed from that, because he could not get quite as good ore mixing, and could not get the ores charged in the exact sequence that he wanted. There is quite a little to that, getting ore and other materials mixed properly. We run with two and one-half men; one man on the larry, one on the hoist, and one man for every two furnaces who can spell these men, and who also keeps the stock yard swept and clean. So you are getting down pretty nearly as low as you can go. Most modern plants keep a record of stocking, and charging costs, which includes unloading ore and

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†Supt. Blast Furnaces, Edgar Thomson Works, C. S. Co., Braddock, Pa.

limestone, and other miscellaneous materials, and their costs average about 16 cents. I would like to hear from the Cambria operators as to whether they are doing much better than that.

This is all fine, and I have enjoyed the paper immensely, but it is not new. It is something which the blast furnace men all over the country, and the electrical engineers, have taken years to develop. It has been the general co-operation all along the line that has accomplished these reduced stocking and charging costs, and it is only by working together in this way that we can accomplish the most efficient developments.

Geo. W. Vreeland*: The question of automatic tops has been quite thoroughly covered by the author of the paper and one or two gentlemen who have made previous remarks and I do not feel as if I can add anything to the previous remarks. We have a considerable number of problems around the steel plant and blast furnace that require attention and solution, and although we are all attempting to cut down labor we don't want to lose sight of the one big fact and that is to raise the general efficiency of our operations from beginning to end. We have wonderful opportunities and if we would apply ourselves mechanically, electrically, chemically and metallurgically to the job we can make a wonderful saving, possibly far more than by eliminating one or two men from some questionable position. The problems I have in mind are of great economic value and in many cases amount to thousands of dollars per day; to these problems we should apply ourselves and help put the great iron and steel business on a firm economic basis.

A. C. Cummins: Mr. Shover's remarks cover a very important part of the electrical maintenance problem. All electrical superintendents face the difficulty of supplying properly trained men to care for the more complicated type of electrical equipment. I sometimes think that the ability of our maintenance men does not increase as rapidly as the complication of the equipment which we install. However, we should not blame the maintenance men, but blame ourselves for not attending to training them properly. I believe it will not be long until the importance of systematic education of maintenance men will receive much greater attention on the part of the plant executives than it does at the present time, and when such practice becomes prevalent, the problem of the maintenance engineer will be greatly simplfied.

Thomas S. Towle: † The paper under discussion is a narrative of the gradual attainment of a goal that was evidently foreseen years ago, and is an inspiring example of the ability to have a vision of what would be ideal and then work unceasingly to that end. Because of the magnitude of each unit that goes to make up the Automatic Blast Furnace, it was obviously impossible for the paper to include details of all these parts. It is possible, however, in the discussion to add to these details.

With regard to the single wire control of the bridging motion of the ore bridge mentioned, mention was made of the use of polarized relays so as to get forward and reverse motion without the complication of added collector rails. It may appear to many present that polarized relays, as commonly recognized, would be too delicate for service on an ore bridge, and so we would point out that polarized relays such as are used for railway signal work were not used, although they were contemplated originally. In their stead, use was made of special contactors which were connected in such a manner that one or the other would be closed, depending upon what polarity was applied to a common point between the two. Thus, the operator in the crane cab, by means of his master switch, could connect the mid-point of these two contactors to either the positive or negative line and thus close either one of the relays, thus securing a circuit for either the forward or reverse direction contactor for the bridging motors. The scheme was really very simple, and successful operation has been secured.

In order to tie in the present paper with papers previously given, it might be well to list several which were presented in the past few years and which dealt with ore bridge control. The first of these is entitled "Controllers for Ore Unloaders and Ore Bridges", and is included in the journal of the A.I.&S.E.E. after its presentation at Pittsburgh, November 17th, 1922, by N. L. Mortensen. The next paper of interest was presented by P. R. Canney at Buffalo, September, 1923, and is entitled "A System of Coal and Ore Bridge Traverse Control for Protection against Wind and Skewage Hazards of Skew Type D.C. Bridges." Another paper entitled "Direct Current Hoist and Trolley Control for Ore Bridges" was presented at a Chicago Meeting of the A.I.&S E.E., December, 1924, by N. L. Mortenson. A reference to these papers we felt would be of value to anyone making a close study of the paper under discussion.

Not a great deal is included in the present paper regarding the Skip Hoist, and therefore I would refer you to two papers recently published in the Journal of the A.I.&S.E.E. regarding skip hoists which should be of interest. These papers are "Single Bucket Blast Furnace Skip Hoist Characteristics" by A. C. Cummins and A. R. Leavitt, presented at the Buffalo Convention, September, 1923. Another paper of interest on this subject entitled "Ore Handling Costs" by Walter Burr, presented at Philadelphia, May, 1923. All of these papers can be found in the records of the A.I.&S.E.E.

Mention was made of the Automatic Skip Hoist Controller at Johnstown, and I might state, to the best of our knowledge it was a first application of what might be called the full automatic principle for blast furnace skip hoist control. You are all familiar no doubt with small automatic skip hoists handling coal and ash, but it remained for these Johnstownengineers to apply the automatic principle to as important a hoist as a blast furnace skip hoist. This particular equipment is operated by means of push buttons, and all the operator has to do is to push a start button which causes the skip to be hoisted to the top of the furnace, dump, and return to the bottom of the incline ready for another load.

Only brief mention was made in this paper regarding alternating current skip hoists, and because of the meagerness of the information available, we believe that a paper on this subject by someone thoroughly familiar with this type of euipment would be greatly appreciated by this Association.

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†Sales Engr., Cutler Hammer Mfg. Co., Pittsburgh, Pa.

To one not familia with the automatic controller for a McKee Furnace Top, the picture shown might impress one that the controller was very complicated. In fact, the scheme is very simple, but the great number of contacts shown is required to take care of the great number of skips which are hoisted and dumped and rotated to various positions on the top. Each set of contacts on the circular contact switches represent the various dumping positions of the loads hoisted, and thus the repetition is required. You will note from the pictures the similarity between the indicating device for the scale car operator and that of the operating switches on this McKee top control panel. In fact, they are both operated by the same type of mechanism, and whereas the indicating device merely shows a dial with the points indicated, the device on a control panel must necessarily carry the contact buttons for the automatic dumping of each load in its proper place. Provisions can be made by contacts for not only indicating the position where the loads are being dumped, by means of indicating lights, but also connection can be made to recording meters so that a permanent record can be secured. This point, we believe, was mentioned by the author of the paper.

The control equipment for the bell hoists are really simple reversing controllers, the particular type depending upon the particular type of bell hoist used. Provision is made on the control panel for regulating the operation of the big bell after a predetermined number of operations of the little bell. This adjustment is very readily made on the control panel.

It was interesting to note the various types of bell hoists described by the author, and in particular the Otis scheme of obtaining a constant sealing pressure by means of lifting a counterweight a short distance above its support. Naturally, there can be many modifications of this scheme and the writer has in mind one very interesting modification which he will describe. Instead of having a separately mounted hoist connected by rope to the bells and counterweights, this particular installation consists of a counterweight running on a track and carrying the operating motor directly on itself. The rope coming from the bell is attached to a rack which is connected to the customary pinion and train of years to this motor. Thus, when it is desired to lower the bell, the motor is operated in the proper direction, which pays out the rack and allows the counterweight to move a few inches to its stop.

After the counterweight bottoms, the motor continues to pay out the rack until the bell is lowered to the proper position, where the motor is stopped, and after a certain time is reversed and hoists the bell to its closed position and then hoists the counterweight on which it is mounted a few inches so as to secure the proper sealing pressure. All of this is under the control of limit switches and occurs automatically after the motion is once started by means of interlocks. A similar device is placed on the large bell, and after a predetrmined number of operations of the small bell, the large bell is lowered automatically, as previously described. This arrangement of the operating motor directly on the counterweight affords a very unique solution of this particular problem.

I believe that the paper presented is one of the most interesting that has been presented to the Association, and it was particularly interesting to me because I had a chance to see the working out of this plan for the simplification of blast furnace operation. I think that you will agree that this piece of work is truly that of a pioneer.

Robert McEldowney*: There is nothing I can say aside from the fact that this apparatus is operating successfully.

Several points have been raised on the question of operating with one man. With the Hoover-Mason system we have at Franklin Works on which this gauge rod is applied, we are operating with two men, originally with three men. It is possible to operate with one man at a plant where they have a McKee bin or similar bin. The Hoover-Mason bin could be designed to do away with the other man. We have our plans drawn up for a new system at our other works, which will have but one man, and that man will be the larry man. There is no reason to worry about that man; there is no danger from the safety point of view, either to the man himself or breakdown of any of the equipment; at least, we do not anticipate any and we are not afraid to go ahead and try it out. As far as costs are concerned, elimination of that man represents a saving of about two cents per ton of iron, which, in these days, seems to be worth while. As far as efficiency of the furnace is concerned, I do not believe any of the blast furnace operators will say that elimination of this sum is a determining factor in the efficiency of the furnace; but there are certainly many of these things, such as skip operation, McKee top distribution, and regular filling which tend to increase the efficiency of a furnace. Just how much that is, it would be hard to show, either in dollars and cents, pounds of coal or tons of iron, because there are other things that enter into those conditions at all times. We believe that it certainly is a step forward to be able to reduce your operating force to the lowest minimum and we do not apprehend any difficulties.

We would be very glad to show anybody just what we are doing, how it is working, and we might even go so far as to show a few costs. When your cost of stocking and charging, as Mr. Maccoun says, is $.14 and you can reduce that by .02, that is a pretty good percentage of that individual cost.

J. C. Barrett†: I have not much to add to the paper, nor much of a criticism to make. I am very glad to hear the paper, and possibly from what I have heard and seen that I may have a thought or two to add. There are some things that are questionable in my mind. The thing of trying to run a blast furnace with one man in the stock yard is a little risky in other ways than which Mr. Shover referred to. You must keep a spare man, because a man is going to get sick or something is going to happen, and if you don't have a spare, you will have to put in a green man and if you do, you will lose some tonnage and get balled up worse than if you had kept your two men.

I would like to add to what Mr. Shover has said, that he was pretty close in touch with developments

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†Supt., Blast Furnaces, Carnegie Steel Co., Youngstown, O.

as they were developed at Ohio Works on Nos. 5 and 6 furnaces on the inter-locking proposition. Mr. Shover, I feel, had done a very good job, and I can assure him it is still going. It has not been changed in any way. However, I think in the new furnace we build we will put in this interlocking proposition. It gives a little leeway. We can charge by this new method and keep ourselves in step when putting in something a little extra; otherwise, we would be simply tied up on the old way. His was the first development.

In regard to the filling, we are at present filling our furnaces with two men, one man on the skip and one man on the larry car. At the six furnaces we require 18 skip men and 18 car men. We must have somebody familiar with the thing, because if we run into some difficulty or the man won't be out and we have got to have a man, we don't have to use a green man. We don't have very many that are in preparation, but we try to have one man at least, or two men per turn, who would be familiar with the duties. That, of course, is added to your cost and added to the expense of operation.

The thing that impressed me is the automatic operation of the gauge rod. We put in a recording gauge, but a man has to operate it. When our chart comes in we know every half hour where the furnace was at that time. But this automatic gauge rod is an additional refinement and I do not see why it cannot well be installed.

One matter about the discussion you had here. In the West they have been operating with one man filling their furnace, etc., getting rid of the skip man, the carman throwing the lever, the skip goes to the top and dumps, while the other comes down and ready for use when he comes back, but just as has been said, unless you are going to improve your bin a little, you cannot do the work with one man. They also need a man for poking the bins.

I am certainly very glad to hear the paper, as it was presented, and the discussion. There were certainly some good thoughts brought out.

H. S. Braman*: I have listened with considerable interest to Mr. Cramer's paper and agree that the electric control has been largely responsible for the reduction in our labor costs, but the savings of one or two men further means little, compared with the vast savings effected in ore, coke and stone, due to more regular filling and distribution and steadier operations generally.

It is safe to say that the Electric Revolving top and the uniform filling has been responsible for a reduction in coke consumption alone equal to no less than 100-lb. coke at $6.00 per ton = 30c savings, or a saving equal to a reduction of one-half of all operating men.

Personally, I believe it is better and cheaper to carry enough men to thoroughly inspect and keep in A-1 condition all machinery and your savings in raw materials will well pay for the effort.

Frank Smith†: Just wish to say a few words in regard to automatic skip hoists. In 1909, we installed single skip hoist at Federal furnaces, South Chicago, No By-Products Coke Corp., which is entirely automatic. The operator starts the hoist, and after reaching the top of furnace, it remains 7 seconds, returning to the bottom of the incline without any attention of the operator. And later on in 1916, we installed a similar hoist at the United Furnace Company, Canton, O., which handles a Neeland bucket.

Phelan McShane: * Mr. Cramer stated in his paper that labor is saved by the methods followed at Johnstown, but he also stated that better operation resulted. The saving of labor is a tangible thing, while the improved operation is difficult to measure. Hence, labor saving has been the theme for most of the discussion.

Regularity in charging, avoidance of interruptions in the sequence of operation of the various component parts of the furnaces charging equipment from stock bin to furnace, is the important item.

Mr. Towle explained the relays referred to in Mr. Cramer's paper as polarized relays. The use of two contactor relays as described by Mr. Towle are frequently employed to operate a controller located some distance from the master switch, or where the controller is located on some moving object, such as a transfer car and the master switch in a stationary position. As stated by Mr. Towle, the scheme is very dependable. I know of four installations made eight years ago by the Westinghouse Company for remotely controlling 36-ton electric locomotives and to best of my knowledge there has not single failure caused by the relays.

Mr. Cramer, in the forepart of his paper, referred to the early records of iron making by Tubal Cain. I am wondering how far civilization would have progressed by this time if Tubal Cain had at his disposal the many electrical devices at the disposal of the present iron makers.

R. M. Hussey†: I have read the paper presented by Mr. Cramer. It is very interesting and is descriptive of carefully planned electrical devices applied to that part of Blast Furnace equipment which must function in the most reliable manner.

I do not believe that much stress should be laid on the man-hour reducing feature of the automatic charging equipment, because of the following points in question.

In the line of man-hours from ore in cars at the dumper to hot metal in the holders, or ore in cars at the dumper to pig iron in cars, do the man-hours eliminated in the stock house by reason of the automatic equipment show up to real advantage?

Do the man-hours eliminated in the stock house by reason of this automatic equipment and better performance of the furnace jusitfy the investment in automatic equipment? It seems to me that the man-hours eliminated in the stock house must show up as an exceedingly small return on the automatic equipment investment and therefore, in order to justify such an investment, improved furnace performance must obtain.

Was the size of either the electrical or mechanical maintenance crew changed and if so, what was the net result?

How have the automatic features affected furnace output tonnage?

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In the case of revamping an old furnace and for good and sufficient reasons, it was decided to change to motor-driven bell hoists, to install a revolving stock distributor at the top and make stock line gauging more reliable, then the added features to make charging fully automatic might be made an attractive proposition for reducing stock house labor one-half or two-thirds.

It will be very interesting to follow the performance of the equipment described by Mr. Cramer.

K. Raynor:* I had the opportunity yesterday to look over the equipment described by Mr. Cramer in his paper. At our Bethlehem plant we have none of those automatic features, except the revolving top. I was sort of skeptical about some of the operations, but after spending some time there yesterday, I was very much impressed by the way the thing has worked out, particularly with regard to the efficiency of the operation and reduction of any lost time between operations. At our Bethlehem plant we are operating our small and large bell with the blast air. We have a sort of tentative plan to do away with the skip operator, whose duties are to operate the skip and large and small bell, by interconnecting the air operated bell valves with the electrical equipment, making this operation automatic.

To those who have not seen the operation of the electrification of blast furnace charging, I think if there is any doubt in your mind as to its reliability or other points, that it can be entirely eliminated by an inspection of this apparatus, which has been described today.

F. W. Cramer: One word with regard to the operating force. We have the same number of men now in the electrical department at the blast furnaces that we had before this automatic equipment went in. There seemed to be a question of safety with regard to one man running the equipment. If we find a way of getting rid of that one man, I really think Mr. McEldowney would go along and make the whole thing completely automatic.

*Elec. Supt., Bethlehem Steel Corp., Bethlehem, Pa.

*Power Generation By Blast Furnace Plant**

By O. C. CALLOW†

WITH the present trend of low market prices and high labor costs, a careful study of all by-products of an industry is essential, as the successful marketing of these by-products will often determine whether or not the manufacturer can show a profit for his operation.

The principal by-product of a blast furnace is gas, the furnace itself being literally a huge gas producer. A modern furnace producing 600 tons of iron in 24 hours, will produce more than 3¼ millions of cubic feet of gas per hour. A certain amount of this gas is used in heating air in the stoves for the hot blast. This, with present-day stove construction, can be taken as 25 per cent of the total gas produced, leaving a surplus of approximately 2½ millions of cubic feet per hour.

There are two modern methods of utilizing this gas in general use—one by burning it under boilers to produce steam, and the other as a fuel for gas engines. Whichever method is used, the gas must first be washed to remove ore and coke dust, and cooled.

It is not the purpose of this paper to discuss the relative advantages of these two methods, but we shall confine ourselves only to a discussion of the first method.

Assuming that one pound of coke will produce 70 cubic feet of gas at the furnace top, and that this gas has a heat value of 91 B.T.U.; we find from **table (1)** that there are 2.490 million cubic feet of gas per hour available at the boiler house for steam production, this gas having a heat value of 227 million B.T.U. A large percentage of this steam produced by the gas will be required in the production of pig iron for blowing engines, pumps, electric power for the various drives, heaters, etc., leaving a surplus of 117 million B.T.U. which, converted into electrical units, is 6000 KW.

TABLE No. 1

Gas per lb. of Coke	70 cu. ft.
Lbs. of Coke per ton Iron	1900
Tons of Iron per day	600
Tons of Iron per hour	25
Lbs. of Coke per hour	47500
Cu. ft. of gas per hour	3325000
Cu. ft. of gas per ton	133000
Heat of gas per cu. ft	91 B. T. U.
Heat of gas per ton	12.1 million B. T. U.
Heat of gas per hour	303 million B. T. U.
Total B.T.U. from furnace gas per hr.	303 million B. T. U.
Required to heat stoves	76 million B. T. U.
Available for steam production	227 million B.. T. U.
Steam required for 4000 HP blower 1000 KW generator for plant load, steam pumps, plant heating, etc	110 million B. T. U.
Surplus heat	117 million B. T.U.
Converted to Electric energy	6000 K. W. hours
Total B.T.U. from Coke Braize per hr	35 million B. T. U.
Converted to Electric energy	1800 K. W. H.
Total surplus power	7800 K. W. H.

In addition to this surplus power, which can be produced from waste gas, a considerable amount of power can be obtained by burning the fine coke (coke braize) which is screened from the coke before it is put into the furnace, and for which there is very little other use. This coke braize can be successfully burned under boilers when fed by mechanical stokers using forced draft. On a 600 ton furnace operating on a coke practice of 1900 lbs. of coks per ton of iron, there will be approximately 66,000 lbs. of coke braize a day or 2700 lbs. per hour screened. This fuel has a heat value of 35 million B.T.U., and when burned efficiently, will produce 1040 Bo H.P. or 1800

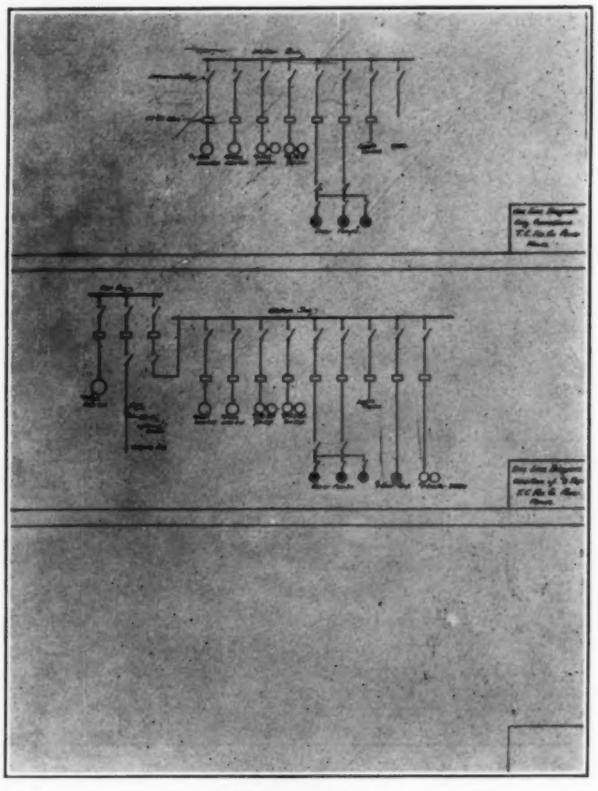
*Presented before Cleveland District Section, May 11, 1925.

†Elec. Engr., Trumbull Cliffs Furnace Co., Warren, Ohio.

KW. per hour. Thus, we find the possibility of producing 7800 KW. Hrs. from surplus fuel.

In estimating the above figures, it must be remembered that ideal conditions are considered. In operating, there are times when this surplus power is not available, such as cast periods and periods of slack wind on the furnace, due to repairs or furnace conditions. During these periods coke braize may be used on several boilers if they are so equipped to maintain the steam pressure; or oil, tar or coal may be used in place of the gas. If there are several furnaces in operation at one plant, these periods of slack wind and low gas pressure can be arranged so they do not coincide, making the power production more continuous.

When a blast furnace is part of a large steel plant the surplus power produced finds a ready use supplying power to other departments of the mill, either



FIGS. 2 and 3

from its own power plant, which can be tied in with the main power plant, or by using the furnace gas direct under the boilers of the main boiler house in combination with coal or coke fired boilers.

When the blast furnace plant is isolated, the problem of marketing this surplus power is more difficult, particularly if there is only one furnace in operation. It is the marketing of the surplus power produced by a single-isolated furnace which we will discuss in detail.

The blast furnace which is rated at 600 tons was first blown-in early in 1922; the boiler house equipment consisting of 5 B&W 800 HP boilers, 225 lb. steam pressure, all arranged for gas firing and coal firing by hand during slack wind periods. The power house euipment operated by this boiler house consists of 2-4000 HP turbo blowers capable of blowing 55,000 cubic feet of air against a pressure of 20 lbs. 2-1000 KW 2300 volt, 3 phase, 60 cycle, 3600 RPM turbo generators, and 2-750 KW synchronous motor generator sets for operating the furnace DC load, with necessary switching equipment. Also three 215 HP steam-driven turbo pumps, 2 boiler feed pumps and steam air compressor, etc. Fig. 2 shows a single line diagram of this equipment.

One of each of these machines was capable of handling the normal load in operation, the others being held in reserve as spares.

Since this equipment requires only about 110 million B.T.U. as shown on table I, there was a large amount of gas wasted, approximately 117 million B.T.U. under ideal conditions.

The problem, therefore, was to find a market for this surplus gas. This was done by contracting with the local utility company whose lines run close to the plant, to sell them power up to 5000 KW per

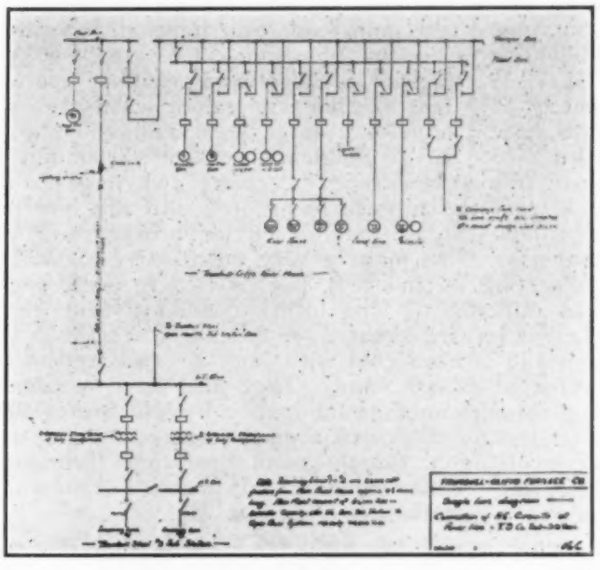


FIG. 4

hour, at a rate which would be determined by the price of coal in their yard.

In other words, since the furnace was producing this power from a by-product, they could afford to sell it at a lower rate than the utility company could make it. This rate would have to be made attractive to them, as they would have to hold sufficient equipment in readiness for operation at all times to handle this load, should the furnace be forced to drop it, due to slack wind, low gas pressure, etc.

To convert this surplus gas into salable power, a 5000 KW 80 per cent P.F. 3600 RPM 2300 volt, 3 phase, 60 cycle turbo generator was installed in the blast furnace power house, together with necessary switching equipment, which will be described later. One of the boilers was also equipped with mechanical stoker and forced draft fan to burn coke braize as well as gas. This equipment was put into operation in July 1922, and shortly after an additional B&W 800 HP boiler was installed, also equipped for coke braize or gas, this boiler being necessary to help keep steam pressure up during short checks on

the furnace by using coke braize on two boilers and also to enable a good load to be carried while any boiler was taken off the line for repairs. This represents the equipment in operation at the present time.

The addition of a machine so much larger than the original equipment of the power house, and the tying into a system having a generator capacity of 60,000 KW, required considerable changes in the switching equipment. This was taken care of by installing an entirely new bus structure located in the power house basement, consisting of a 2000 Amp. generator oil circuit breaker, a 2000 Amp. outgoing feeder breaker tied into the utility company's lines, and a 600 Amp. breaker tying the new bus into the original plant bus. A single line diagram of these connections is shown in Fig. 3.

Connections were made from the outgoing feeder to the utility company pole line through 6-3 conductor 250,000 Cm lead cables. Connected between these cables and the disconnect switches are 3-2000 Amp. choke coils and oxide film lightning arresters. The utility company pole line consists of 9-500,000 CM W.P. cables on wooden poles running approximately 1200 feet to their sub-station. This sub-station which supplies a large steel mill is equipped with 6-2000 KVA Single phase 23000/2300 volt 60 cycle transformers with necessary switch gear, the line from the furnace being tied into the low tension bus, through an oil circuit breaker and disconnects. This made a very inexpensive method of connecting up this line, but has led to some operation difficulties. The utility company main power plant is located about three miles from their sub-station and is connected with same by two feeders operated at 23,000 volts. They also have a connection through another sub-station by which they have interchange of power over a super power system at 66,000 and 132,000 volts operating throughout Ohio and Pennsylvania. The connection of the transformer sub-station is shown in Fig. 4.

The original intention was to operate the 5000 KW generator in parallel with one of the 1000 KW machines tying the common load into the utility company's lines. Considerable trouble was experienced while operating in this manner, due to unsteady voltage, line disturbance and surges resulting in the loss of power at the furnace plant causing the shutting down of the pumping station. This condition of course was most undesirable, particularly so as it took some little time to prime these pumps and get them back on the line. This system of operation was therefore discontinued and the two machines were run separately, the 1000 KW machines supplying the important plant load. In order to proportion the load on these machines a transfer bus was installed in connection with the plant bus structure and all disconnect switches made double throw, as shown in Fig. 4. With this arrangement, any feeder could be switched to either the plant bus and operated from the 1000 KW machines, or to the main bus and operated from the 5000 KW machine. In this way approximately full load is kept on one of the small machines which at the present time consists of the important river pumps, and the coke plant load, which is an ideal load for this machine, averaging 1000 KW per hour per month and varying from 900 to 1100 KW.

The other 1000 KW machine can be run in parallel with the 5000 KW on the utility company lines when steam and gas conditions will permit. This is done by throwing the disconnect switches of the machine to the transfer bus instead of to the plant bus. The two 750 KW M-G sets are normally operated in parallel during the day, and one is shut down at night; they are connected to the transfer bus and thus operated from the 5000 KW machine. Inasmuch as these machines have several large motors connected to them running from 200 to 350 HP, there are times when very severe peaks are handled, running as high as 1200 KW. This load is therefore much better handled by the 5000 KW machine than the 1000. The entire plant lighting is carried on the plant machine. Since this machine is controlled by a voltage regulator a very steady voltage is maintained, this being a very important feature in the life of the lamp in the plant and also in the operation of the large pump motors.

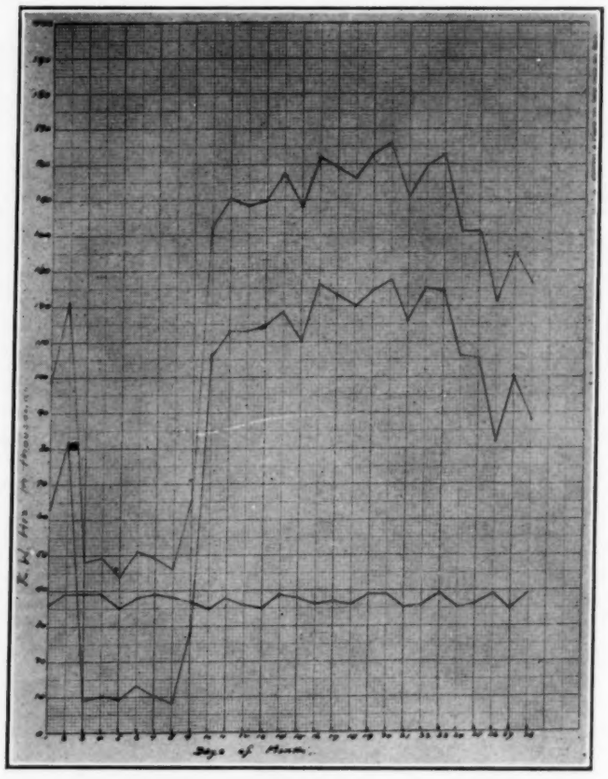


FIG. 5

No regulator is provided for the 5000 KW machine and owing to the voltage conditions on the utility company line, there is little need of one. Once the machine is tied into the utility company system, full excitation is put on. By this over-excitation, the system voltage is boosted. This excitation is maintained under all load conditions. When operating at full load a 95 per cent P.F. is thus carried; this fact has enabled a load of 7000 KW to be carried on this machine, which is very little in excess of full load current. On the other hand, on light loads the effect is to improve the system power factor with a resultant high amperage per KW output, thus being well within the range of the machine.

The output of this machine is regulated entirely by hand, by means of the electrically operated speed changer, common to most machines for synchronizing. The amount of load carried depends upon the boiler house steam pressure, a straight line steam chart being the objective. As the steam falls the operator slows up the machine dropping load; as the steam rises he also raises his load. The operation of the furnace determines what this steam pressure should be held at. If the blowers are working against high pressure, the steam must be carried very near the pop-off pressure of 225 lbs., or volume will be lost; under good conditions a variation of 225 to 210 lbs, is permissible.

In the case of a check on the furnace, the load is cut off and the machine allowed to float on the

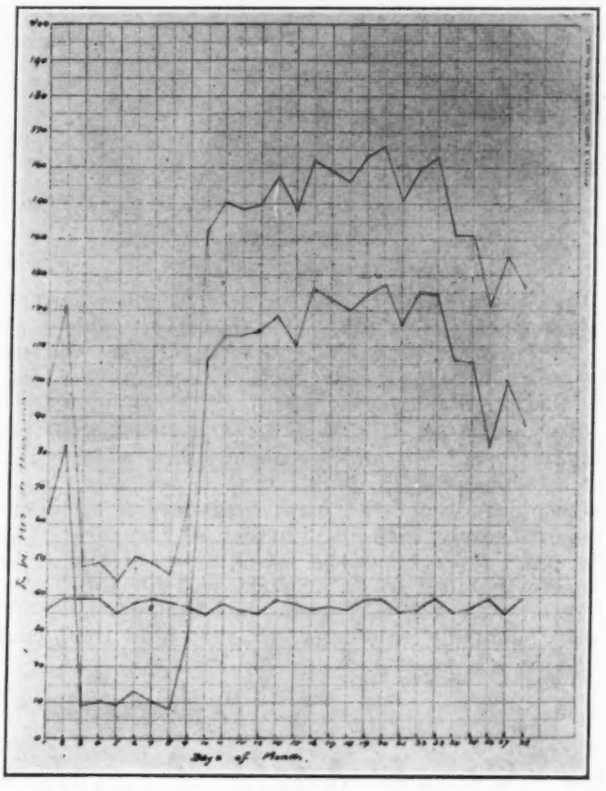


FIG. 6

line. If the steam cannot be held up in this way, the machine is shut down. The utility company is informed at all times when a shut-down is necessary, in order that they may make provisions to handle the load which the furnace plant drops.

When the 5000 KW machine is thus shut down all feeders which were connected to the transfer bus are fed direct from the utility company lines, as the condition only occurs at times when there is no gas coming from the furnace and steam is low; it is an advantage to be able to operate in this manner since none of the plant load has to be curtailed. The watt hour meter reverses during this time and when the machine is again switched on the amount of power which was used is soon made up.

In the event of the 5000 KW machine having to be shut down for repairs, the second 1000 KW machine is operated in its place, taking care of the plant load and supplying the balance to the utility company.

No trouble is experienced in synchronizing either of these machines in with the utility company lines, this being done in the usual manner. Should any trouble develop at the sub-station causing the oil switches on the high or low tension side of the transformers, or the feeder oil switches at the utility company power house to open, the outgoing feeder switch at the furnace must be opened before the line or sub-station can be connected in again, since there is no provision for synchronizing except at the furnace plant. After the trouble is cleared, the switches are closed and the furnace operator notified that he can synchronize in. Although there is a possibility of severe damage to equipment of both companies should a mistake be made, in this method of operation the only remedy would be to run the tie line from the furnace direct to the main power plant instead of tying into the transformer sub-station, the expense of which would be prohibitive.

A power chart for a 29 day month is shown in Fig. 5 showing on curve 1 the total power generated per day—curve 2 the amount of power sold, and curve 3 the power consumed by the blast furnace plant. This curve represents a typical month early last year before the Company's coke plant was put into operation. All steam produced was used at the furnace. It will be noted that the average hourly power sold for the month is 5400 KW, while the average of the maximum day is 6500 KW. To obtain this average throughout 24 hours a load exceeding 7000 KW must be carried for several hours. The total power generated in this month of 29 days is shown as 4,458,400 KW hours, giving an hourly average of 6420 KW produced by three machines, the total capacity of which is 7000 KW.

TABLE No. 2

MONTHLY POWER PRODUCTION

Chart No. 5

	Per-month	Av. per hr.
Total K.W. hours generated	4458400	6420
Total K.W. hours sold	3742800	5400
Total K.W. hours used	715600	1020
Maximum day K.W. hours generated	182400	7600
Maximum day K.W. hours sold	156000	6500

Chart No. 6

Total K.W. hours generated	3415000	
Total K.W. hours sold	2375000	
Total K.W. hours used	1040000	1550
Maximum day K.W. hours generated	166000	6920
Maximum day K.W. hours sold	127000	5300
Maximum day K.W. hours used	39000	1630
Av. per hour of maximum day, Chart #5—7600 K.W.		
Av. per hour of maximum day, Chart #6—6920 K.W.		
		680 K.W.

TABLE No. 3

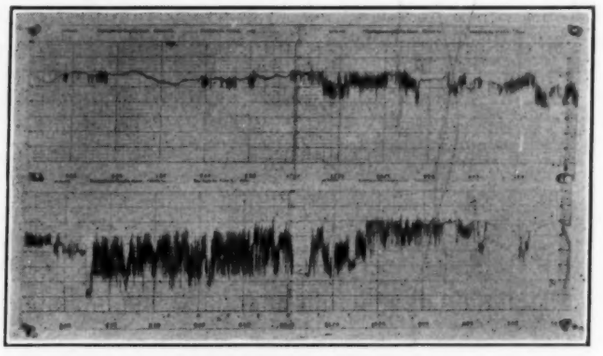
Total B.T.U. from furnace for steam production (table No. 1)	227 million B. T. U.
Total B.T.U. from Coke Braize	35 million B. T. U.
Total B.T.U. available for steam	262 million B. T. U.
Required at Furnace	90 million B. T. U.
Required at Coke Plant	25 million B. T. U.
Available for Electric power	147 million B. T. U.
Converted to Electric energy	7500 K. W. hours
Furnace and Coke Plant electric load	1500 K. W. hours
Surplus Power	6000 K. W. hours

It will be noted that every seventh day the power produced and sold is very much reduced; this is caused by the fact that each these days represents a Sunday when the load on the utility company's system is very light, due to most of the industrial plants being down. The load on the system is split equally between the two power plants. The furnace load is nearly uniform and averages 1020 KW hours.

Fig. 6 represents a power chart for a month of this year and is interesting as a comparison with the former one as shown on table 11. This chart represents conditions with the coke plant in operation. The plant load has increased, averaging 1550 KW per hour instead of 1020 KW., thereby decreasing the amount of power which is sold to the utility company. In addition, a considerable amount of live steam is furnished to the coke plant, estimated at 750 Bo HP per hour. With this deduction a maximum day of 166,000 KW hours can be considered a better performance than the 182,000 KW hours shown on chart 6, being only 16,000 KW hours less or 670 KW per hour. Referring to table III under present operating conditions we find 147 million BTU available for electric power production, this representing 7500 KW hours. Deducting 1500 KW hours for plant load, leaves a surplus of 6000 KW hours. This compares very favorably with the average of the maximum day shown on table II as 5300 KW.

This improvement has been brought about by installing better gas burners, soot blowers and other plant improvements.

It will be noted that practically no power was sold from the 3rd to the 8th of this month; this was caused by the 5000 KW machine being down for repairs. The two 1000 KW machines produced an average of 47,000 KW Hrs. per day for these six days, giving an hourly average of 1950 KW. Two sections of a graphic wattmeter chart are shown in Figs. 7-8. This meter is connected at the furnace company switchboard in the outgoing feeder and represents all power supplied to the utility company's power lines. Fig. 7 shows a good steady load with every little swing. The 5000 KW machine was operated alone at this time showing a little better than full load. It will be noted that there is practically no depression in the output at cast time, showing that the steam was kept up at this time. Fig. 8 shows an entirely different chart. Heavy swings are encountered, running as high as 2500 KW. These swings are caused by conditions of load on the utility company lines. This type of load is not so desirable as that shown on chart No. 7, since the load must be cut enough so that the maximum peak is



FIGS. 7 and 8

within the setting of the protective relays on the outgoing-feeder switch. These relays which are of the reverse time element type, are set at 2000 Amps. The charts are both typical of the load handled.

In conclusion, it should be stated that with two furnaces available and producing gas, a load considerably more than double that shown above could be produced, since the plant load does not increase proportionately with the number of furnaces. Furthermore, there would be fewer times of low steam causing the load to be dropped, and for this reason a better rate per KW could be obtained, since the utility company would not have to hold their euipment in reserve to pick up this load.

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*The Static Condenser On Steel Mill Loads**

By R. W. DUDLEY†

BEFORE attempting to give you any information on the operating results obtained with static condensers, I would like to add a few remarks to the now voluminous information on the general subject of power factor and attempt to set this problem before you on a basis slightly different from that generally used. It has been my experience that the question of power factor correction, as usually presented to a steel plant organization, is generally somewhat confusing and indefinite to those who may not have recently familiarized themselves with alternating current phenomona. Any of you who have attempted to explain "Power Factor" to some one who falls in that class have probably had the same experience. This elusive characteristic of power factor and the difficulty in giving a clear explanation of it may explain in part why it has been some times neglected in our steel plants and why the power producers have been forced to adopt rather vigorous measures directed towards its improvement. Power factor has a direct bearing on costs of power production, transmission and consumption and therefore deserves proportionate share of the consideration usually given to those factors. It seems reasonable to the writer, therefore, that an attempt to place the general problem of power factor correction on a more simple and easily handled basis would be of interest to this gathering.

My discussion will be confined entirely to the correction of "lagging" power factor, as I assume

*Presented before Philadelphia Section, A.I.&S.E.E.

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that very few plants represented here tonight are seriously troubled with leading power factor.

Doubtless each of you men assembled here have a feeling of familiarity with Power Factor. In general you know what it is and have some idea of its range and value on your plant load. But if I would ask each of you to write out at this moment your definition of power factor, there probably would be some mental agitation and some delay before all the papers were in and there would doubtless be three or four different answers to the question. Some might say that power factor was the cosine of that angle which measured the phase difference between current and voltage in an alternating current circuit. Others might say it was the ratio of the KW energy component to the total kilovolt amperes of an alternating current power load. Or it might be stated as the ratio of the actual power

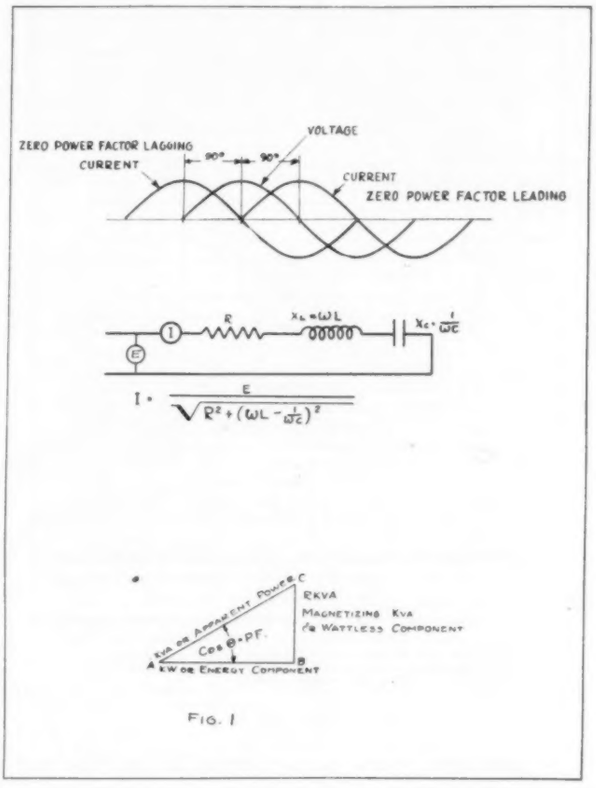

FIG. 1

FIG. 1

to the apparent power in an alternating current circuit, while others might draw a vector diagram showing the energy component and the "wattless KVA" and thus define it graphically. All of the answers would be substantially correct and yet every one of them must be more or less confusing to anyone who may not be familiar with alternating current phenomena.

Unfortunately, perhaps, the phrase "Power Factor" is firmly fixed in the terminology of electrical men and it is almost impossible to escape its use. However, its importance as a confusing descriptive phrase can be minimized by the use of a simple definition and to that end the less involved of the illustrations given above is used here, i. e., "The power factor of an alternating current load is the

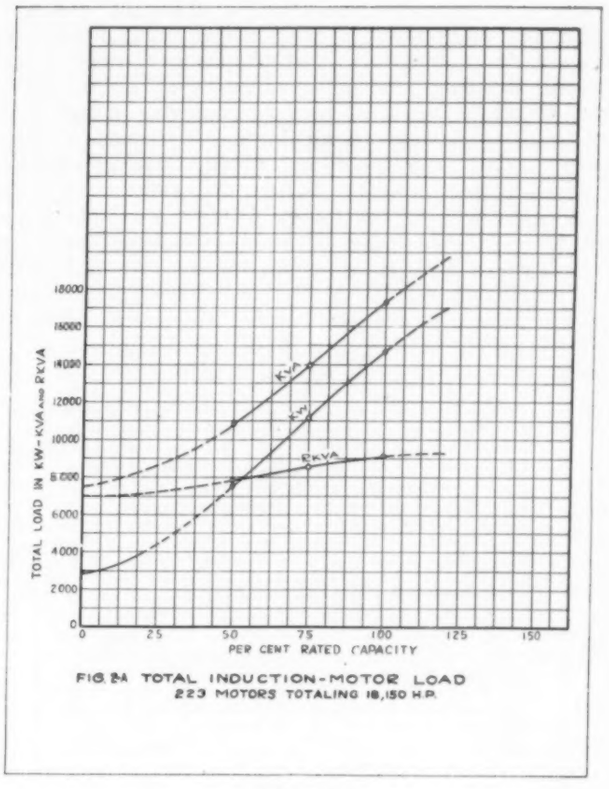

FIG. 2A TOTAL INDUCTION-MOTOR LOAD
223 MOTORS TOTALING 18,150 H.P.

FIG. 2A

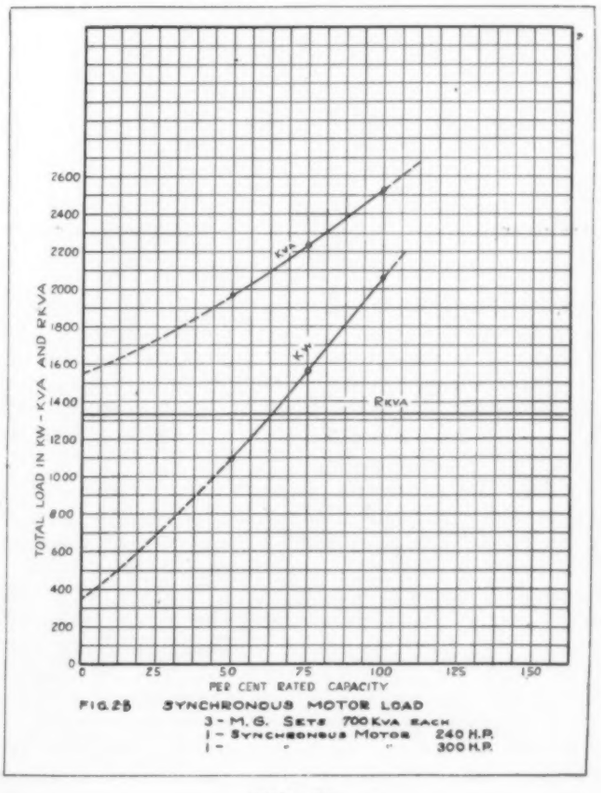

FIG. 2B SYNCHRONOUS MOTOR LOAD
3 - M. G. SETS 700 KVA EACH
1 - SYNCHRONOUS MOTOR 240 H.P.
1 - " " 300 H.P.

FIG. 2B

ratio of the actual power to the apparent power." A further statement of why there is a difference between "actual" power and "apparent power" may also be helpful. Before covering that point, however, it might be well to recall at this point that the induced current in an inductive circuit at any given instant is proportional to the rate of change of flux in that circuit. When the voltage is at a maximum the rate of change of flux is a minimum and when the voltage is at a minimum the rate of change of flux is at a maximum. As indicated by Fig. 1 this results in the inductive current lagging in phase 90 degrees behind the energy current and voltage. On the other hand the harmonic alternating current in a condenser circuit at any instant

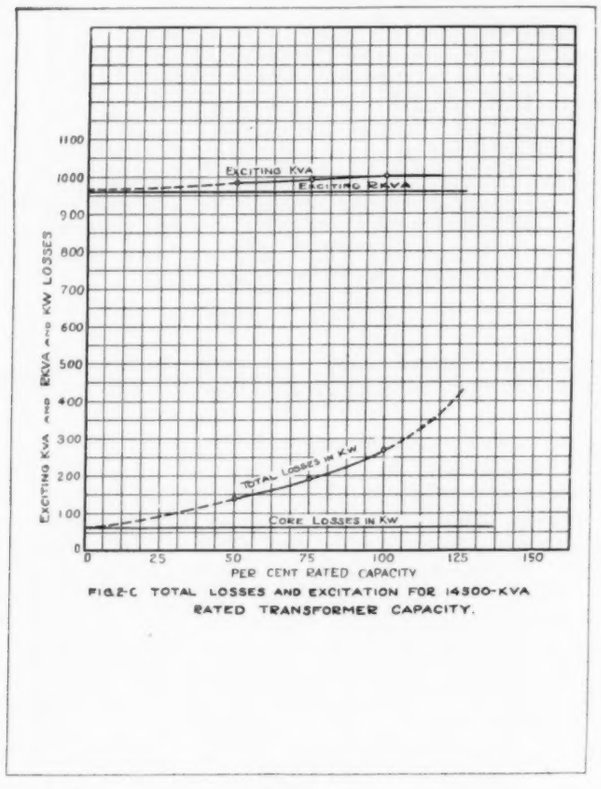

FIG. 2-C TOTAL LOSSES AND EXCITATION FOR 14300-KVA RATED TRANSFORMER CAPACITY.

FIG. 2C

is proportional to the rate at which the charge on the condenser varies. When the voltage is at a maximum the charge in the condenser has reached a constant value, when the voltage is at a minimum the condenser is discharging at its maximum rate. This results in the capacity current leading the line voltage by 90 degrees.

When the "apparent power" in an inductive circuit is not equal to the "actual power" it can be shown to be the resultant of two current components, one an "energy" component and the other a so-called "watt-less" component. (Fig. 1). The energy current is in phase with the line voltage and is used in performing useful work or supplying heating losses; the "wattless" current lags 90 degrees behind the line voltage and is expended in furnishing alternating excitation for the various pieces of inductive equipment connected to the circuit. The "wattless current" is an excitation current originating as an energy current but continuing to oscillate back and forth in the circuit by the expenditure of only sufficient additional energy necessary to overcome its losses. It is therefore not measured by a watt meter so connected as to measure energy but is readily measured as the "reactive component" or "wattless KVA" by the same meter when properly connected for that purpose. It is the effect of this excitation or magnetizing current throughout the alternating current circuit which causes the difference between "actual power" and "apparent" power and furthermore is the only reason for that difference. In expressing the difference between the quantities we resort to a ratio or percentage and introduce the term "power factor," with its more or less elusive and confusing effect. However its

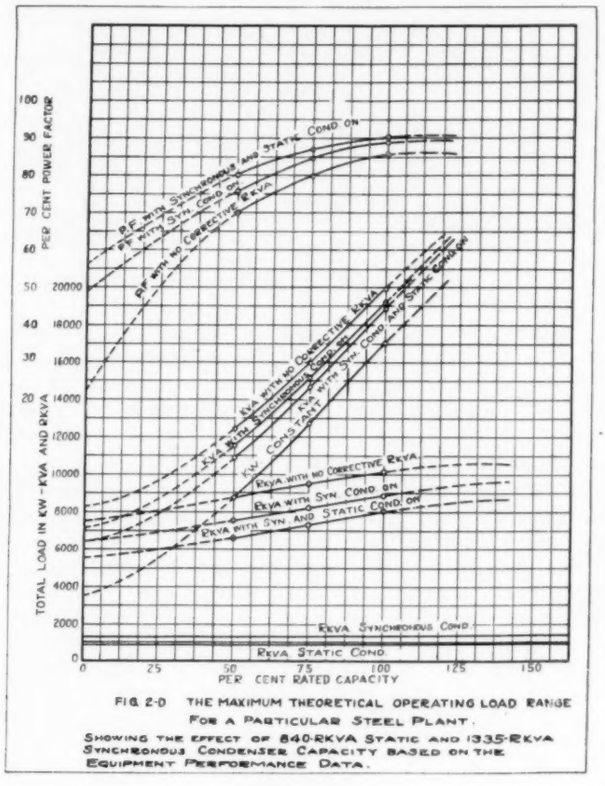
PER CENT POWER FACTOR
PF WITH SYNCHRONOUS AND STATIC COND ON
PF WITH SYN COND ON
PF WITH NO CORRECTIVE RKVA
KVA WITH NO CORRECTIVE RKVA
KVA WITH SYN COND ON
KVA WITH SYN AND STATIC COND ON
KW CONSTANT
RKVA WITH NO CORRECTIVE RKVA
RKVA WITH SYN COND ON
RKVA WITH SYN AND STATIC COND ON
RKVA SYNCHRONOUS COND.
RKVA STATIC COND.
TOTAL LOAD IN KW - KVA AND RKVA
PER CENT RATED CAPACITY

FIG. 2-D THE MAXIMUM THEORETICAL OPERATING LOAD RANGE FOR A PARTICULAR STEEL PLANT. SHOWING THE EFFECT OF 840-RKVA STATIC AND 1335-RKVA SYNCHRONOUS CONDENSER CAPACITY BASED ON THE EQUIPMENT PERFORMANCE DATA.

FIG. 2D

use is justified by its convenience in calculation as well as in discussion and appears as usual in this paper.

To any one who may not be familiar with alternating current circuits and their problems, this explanation may or may not be satisfactory, but it should at least pave the way for a clear cut statement of the real problem involved in the correction of lagging power factor, which I submit is simply this: How can we most economically, effectively and conveniently provide the necessary magnetizing current for our inductive apparatus? For the purpose at hand it may be said that magnetizing current is required for the feeder circuits, transformers, induction motors and miscellaneous A. C. coils, throughout the plant. To obtain this necessary magnetizing current direct from the feeder circuits is simple and convenient and sometimes fairly economical. But in many steel plants utilizing induction motors for mill drives, the magnitude of this mag-

netizing current becomes such a large percentage of the total current that it sometimes becomes very desirable from an economical standpoint to supply this magnetizing current from some source other than the power lines. As an illustration of what may exist in a steel plant load the series of curves shown as Figs. 2-A-B-C-D, have been prepared from manufacturer's data. They apply to a plant with a total rated capacity of 18000-HP in induction motors, 2060 KVA in synchronous motors and 14500 KVA in active transformers. You will notice that these calculated curves show a relatively small change in the value of this magnetizing KVA throughout the load range of the plant. By the use of a KVA meter values of actual load conditions were obtained and plotted as shown in Fig. 3. The

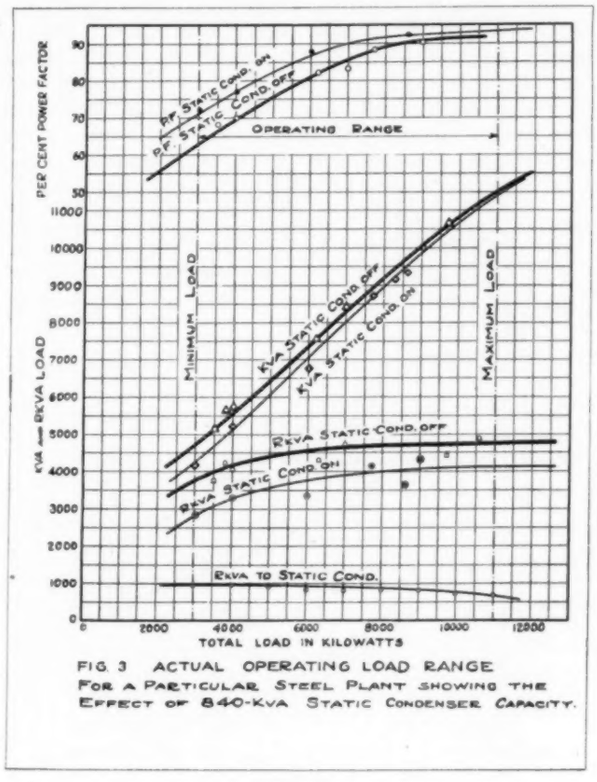

FIG. 3 ACTUAL OPERATING LOAD RANGE FOR A PARTICULAR STEEL PLANT SHOWING THE EFFECT OF 840-KVA STATIC CONDENSER CAPACITY.

FIG. 3

operating range lies within the zone as indicated and shows a 142 per cent variation in energy load from 4750 KW to 11500 KW while the magnetizing current shows a variation of only 27 per cent, from 3700 RKVA to 4200 RKVA. A comparison of these two curves will readily show that although the magnetizing KVA is relatively constant the power factor varies over a wide range and clearly shows the elusive and evasive character of this active variable. Its actual variation is shown in the upper portion of the chart. Incidentally the fainter lines on this chart show the actual effect on magnetizing current and power factor when 840 KVA in static condensers is applied to this load.

The real problem then facing the power producer and consumer is to bring this excitation current within economical limits and power factor, as such, is then automatically corrected the necessary amount. Those limits vary under different

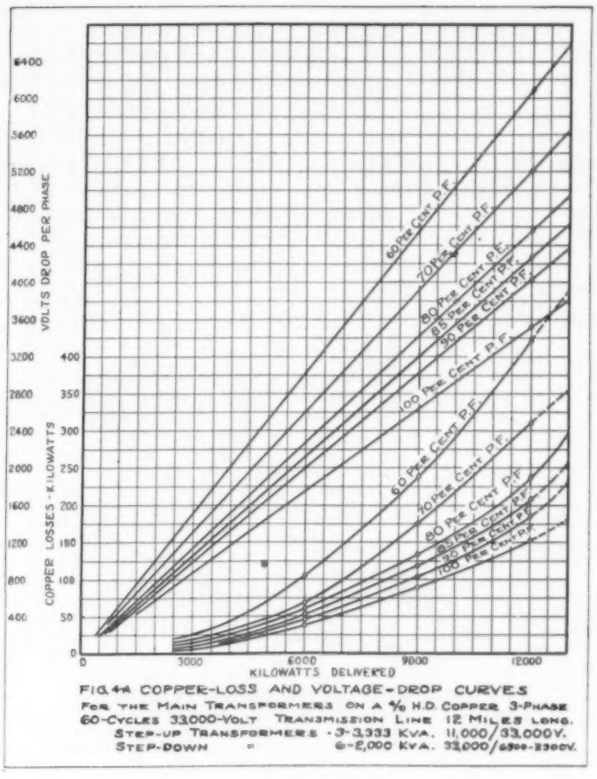

FIG. 4A COPPER-LOSS AND VOLTAGE-DROP CURVES FOR THE MAIN TRANSFORMERS ON A ⅞ H.D. COPPER 3-PHASE 60-CYCLES 33000-VOLT TRANSMISSION LINE 12 MILES LONG. STEP-UP TRANSFORMERS - 3-3333 KVA. 11,000/33,000V. STEP-DOWN " 6-2,000 KVA. 33,000/6900-2300V.

FIG. 4A

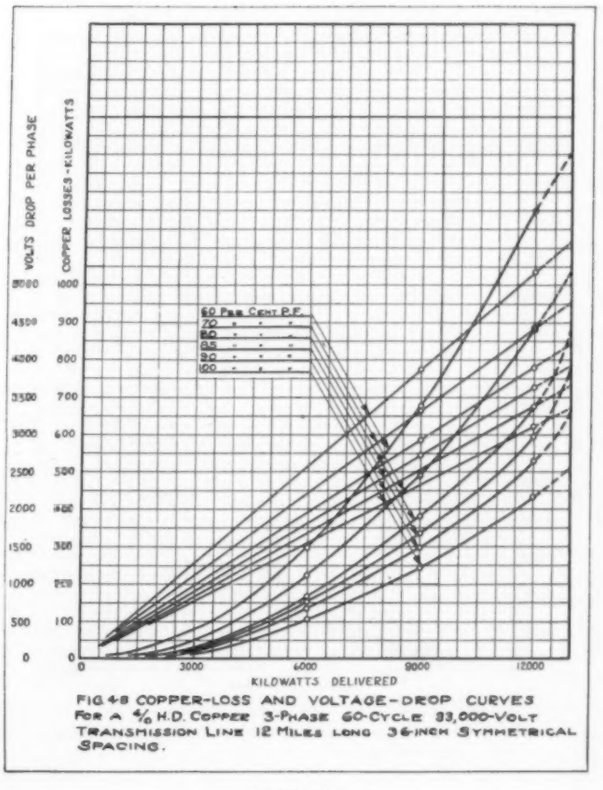

FIG. 4B COPPER-LOSS AND VOLTAGE-DROP CURVES FOR A ⅞ H.D. COPPER 3-PHASE 60-CYCLE 33,000-VOLT TRANSMISSION LINE 12 MILES LONG 36-INCH SYMMETRICAL SPACING.

FIG. 4B

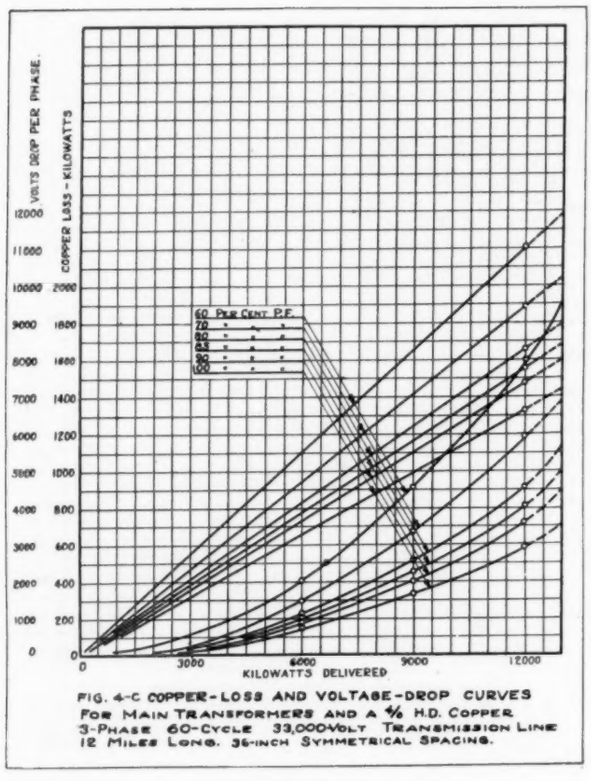

FIG. 4-C COPPER-LOSS AND VOLTAGE-DROP CURVES FOR MAIN TRANSFORMERS AND A ⅘ H.D. COPPER 3-PHASE 60-CYCLE 33,000-VOLT TRANSMISSION LINE 12 MILES LONG. 36-INCH SYMMETRICAL SPACING.

FIG. 4C

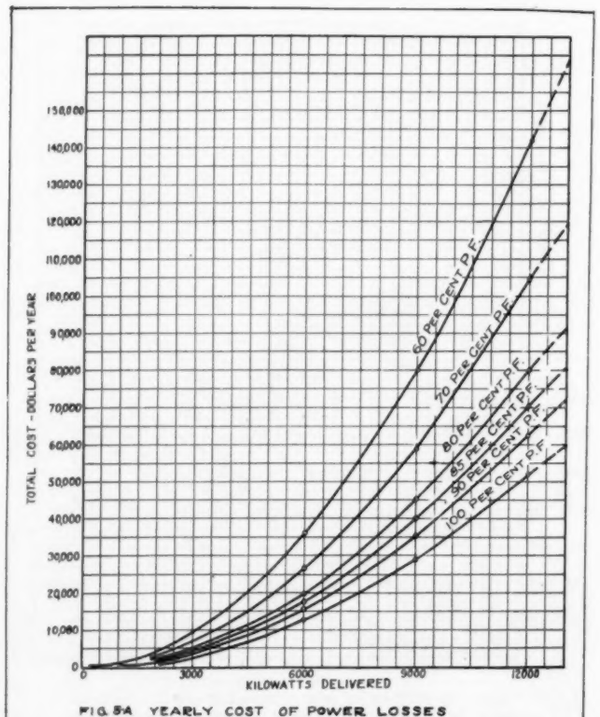
TOTAL COST - DOLLARS PER YEAR
60 PER CENT P.F.
70 PER CENT P.F.
80 PER CENT P.F.
85 PER CENT P.F.
90 PER CENT P.F.
100 PER CENT P.F.
KILOWATTS DELIVERED

FIG. 5A YEARLY COST OF POWER LOSSES IN TRANSFORMERS AND LINE REFERRED TO FIG. 4-C WITH POWER AT 1.0 CENT PER KW. HR

FIG. 5A

conditions, but in general it may be said that the furnishing of alternating excitation current from the power house requires:

(1) Increased generator capacity.
(2) Increased transformer capacity.
(3) Increased line capacity.
(4) Increased I^2R losses in generator transformer and line.
(5) Poorer voltage regulation in generator transformers and line.

While generating equipment is usually proportioned and designed for efficient operation at 80 per cent P. F. the effect of a power factor lower than this figure may become quite serious, for not alone do generator and transmission losses increase, but the prime movers may be prevented from operating at rated capacity, which results in poor station economy and reduced station capacity. For a given energy load, transformer and line capacity, as well as voltage regulation, will vary directly with the power factor while I^2R losses will of course vary

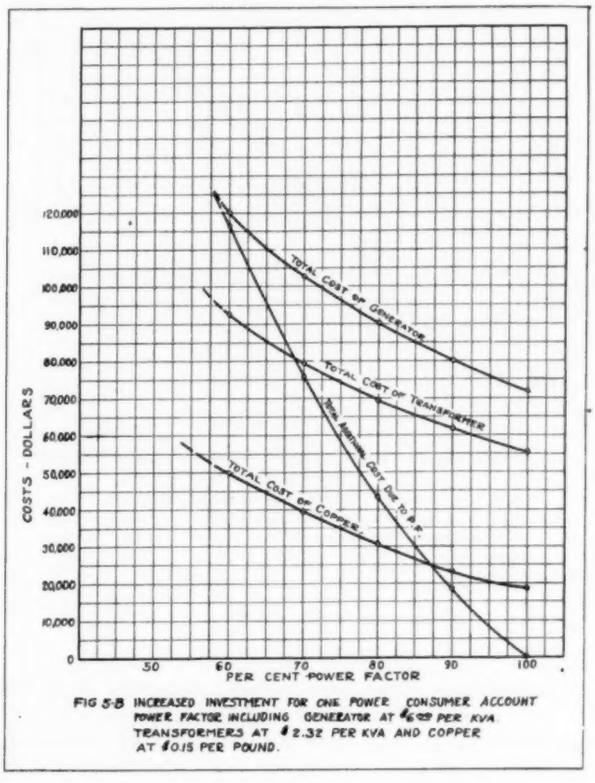

FIG 5-B INCREASED INVESTMENT FOR ONE POWER CONSUMER ACCOUNT POWER FACTOR INCLUDING GENERATOR AT $6.00 PER KVA. TRANSFORMERS AT $2.32 PER KVA AND COPPER AT $0.15 PER POUND.

FIG. 5B

at a much more rapid rate. The series of curves shown in Figs. 4-A-B-C have been prepared to show clearly what happens in a particular transmission equipment as power factor changes or, in other words, as the flow of magnetizing current increases. You will note that the losses are expressed as "volts," "kilowatts," or "dollars" and not in the usual "per cent," for these terms usually speak loudest to an operating man. Good voltage regulation is of prime importance to every steel plant and the curves in Fig. 4-C show the effect of magnetizing current in the voltage supply at a particular plant due to volts drop in transformers

and line at various power factors. Except for very short lines the transformer "drop" is of but relatively small magnitude.

You have doubtless noticed a marked revival of interest and discussion in this question of power factor improvement, particularly on the part of the power producers. They appeared to welcome the arrival of the "synchronous induction" motor as though it were a break in the drouth.

They have reason for this cordial feeling every time they see figures showing line losses and investment costs incurred for the benefit of those who obtain their magnetizing current from the line and pay their power bills on watt meter reading without reference to KVA. The curves shown in Fig. 5-A and 5-B express these costs in dollars to the power producer who might be selling his pro-

FIG 6

INDUCEMENT FOR POWER FACTOR IMPROVEMENT OFFERED BY POWER PRODUCERS IN VARIOUS STEEL CENTERS

Power Producer	District	Demand Charge Based on Kw-Kva	No Penalty Power Factor Range	Penalty or Bonus Applies to	Method of Applying		Remarks
					Penalty	Bonus	
1	Chicago	?	85-100	—	None	None	Requires Customers Maintain 85% or Better - Insists on Use of Syn Motors 50 HP or Larger
2	Cleveland	K.W.	60-75	Demand	Ratio 60/AV	Ratio 75/AV	If Voltage Unsatisfactory-Customer Shall Install Regulator at His Own Expense - Or Demand Will Be Based on 75% Kva of Connected Apparatus
3	Cleveland	K.W.	80-90	Demand	85/Actual	85/Actual	Spot Welders Add 50% of Their Rated Capacity to Maximum Demand
4	Pittsburgh	Kva or Kw or Bonus	—	Demand	Direct on Kva Demand	5% on Kw	Bonus Inducements for Line Regulation on Pf of 90% Leading or Better
5	Pittsburgh	Kw	75	Total Bill	The Ratio of Kwhr to Kw Demand		No Bonus for Leading P.F.
6	Youngstown	Kw	85	Demand	85/Actual	85/Actual	No Extra Bonus for Better than 1.00 P.F.
7	Tri-State	Kw	85-90	Kw	Kw.a (1+K)	Kw x (1-K)	Fixed Per Cent Increase or Decrease in Kw. Hrs. Depending on Average Power Factor
8	Philadelphia	Kw	85 90 95	?	?	?	Permissable Pf Approaches Unity as Demand Increases

PLATE NO 7

FIG. 6

magnetizing current adjacent to the spot where it will be used. Just how desirable this may be at any given steel plant depends largely on the conditions of power supply and usage at that plant.

Furthermore, granting that it may be desirable from either a voltage regulation or economy standpoint to furnish magnetizing current locally, there yet remains to determine the most desirable method with the accompanying questions of costs and operating characteristics. Considering first the plan of furnishing corrective or magnetizing current at a central supply point for a group of inductive apparatus there are two general methods which may be used:

Synchronous condensers which may either float idly on the line or as synchronous motors to drive some uesful energy load and carry sufficient over

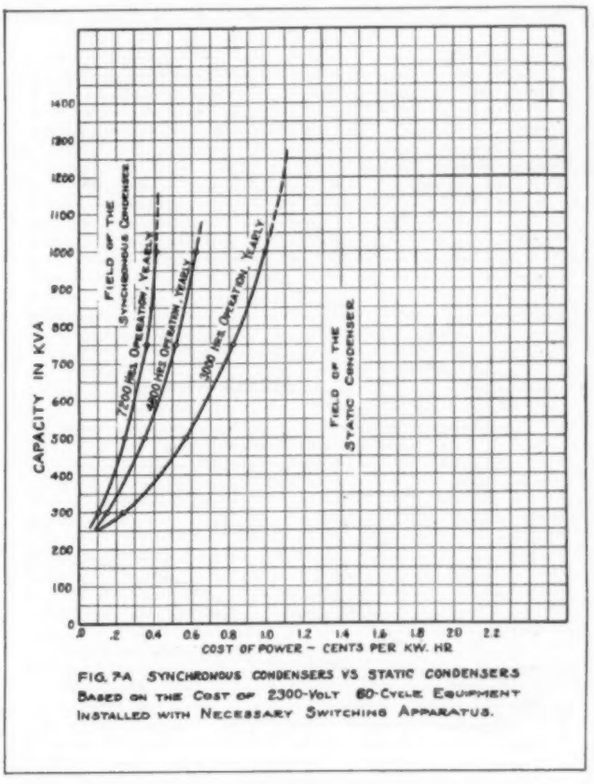
CAPACITY IN KVA
COST OF POWER - CENTS PER KW. HR.
FIELD OF THE SYNCHRONOUS CONDENSER
7200 HRS OPERATION YEARLY
6000 HRS OPERATION YEARLY
3000 HRS OPERATION YEARLY
FIELD OF THE STATIC CONDENSER

FIG. 7A SYNCHRONOUS CONDENSERS VS STATIC CONDENSERS BASED ON THE COST OF 2300-VOLT 60-CYCLE EQUIPMENT INSTALLED WITH NECESSARY SWITCHING APPARATUS.

FIG. 7A

duct at 1 cent per KW hour and delivering it some 12 miles away at 33000 volts. As evidence that the power producers in the iron and steel districts are fully aware of this condition the following table (Fig. 6) is presented to show the various plans they offer to induce the consumer to improve his power factor, i. e., furnish his own magnetizing current. This table indicates that 85 per cent or better seems to be the preferred range and further that the power producer wants to be relieved of the burden of furnishing magnetizing current. Incidentally it shows that there might be possibilities of simplifying rate schedules without material injury to either producer or consumer.

It would seem that sufficient information has been brought out in the previous curves and tables to indicate the desirability of storing or producing excitation to provide corrective KVA, or Static Condensers:

Synchronous condensers as such, compared with static condensers, have the advantage of lower first cost, and in combination with regulating equipment, lend themselves readily to automatic regulation of line voltage or power factor correction. However in common with all rotating apparatus they require some measure of attention and require power to operate while static condensers require much less attention and a minimum power to operate. Remembering that it is not difficult to train attendants to switch condenser banks on or off the line as the need arises and thus obtain a more or less ready adjustment of condenser capacity, an examination of the curves in Figs. 7-A-B-C will show a rather restricted economic field of usefulness for the syn-

chronous condenser. This data is based on 3-phase, 60-cycle, 2300-volt power supply with power costs within the usual steel plant range and with fixed charges of 15 per cent, based on total cost of the unit ready to run.

No charges for attendant or maintenance are included, both of which favor the static condenser. With power costing less than six mills and in capacities less than 500 KVA the static condenser will show a smaller yearly cost than the synchronous condenser, including fixed charges and power losses if operated only 10 hours per day. For longer periods of operation even in larger capacities they practically have the field to themselves in these days of steadily advancing fuel costs, insofar as operating economy goes.

The 80 per cent power factor synchronous motor driving a direct current generator is in quite general

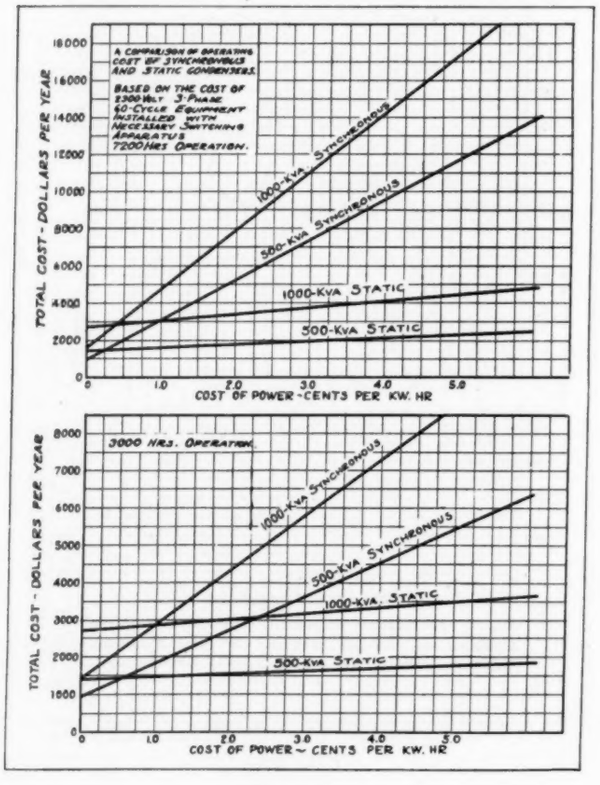
A COMPARISON OF OPERATING COST OF SYNCHRONOUS AND STATIC CONDENSERS.
BASED ON THE COST OF 2300 VOLT 3-PHASE 60-CYCLE EQUIPMENT INSTALLED WITH NECESSARY SWITCHING APPARATUS 7200 HRS OPERATION.
1000-KVA. SYNCHRONOUS
500-KVA SYNCHRONOUS
1000-KVA STATIC
500-KVA STATIC
TOTAL COST - DOLLARS PER YEAR
COST OF POWER - CENTS PER KW. HR
3000 HRS. OPERATION.
1000-KVA SYNCHRONOUS
500-KVA SYNCHRONOUS
1000-KVA STATIC
500-KVA STATIC
TOTAL COST - DOLLARS PER YEAR
COST OF POWER - CENTS PER KW. HR

FIG. 7B

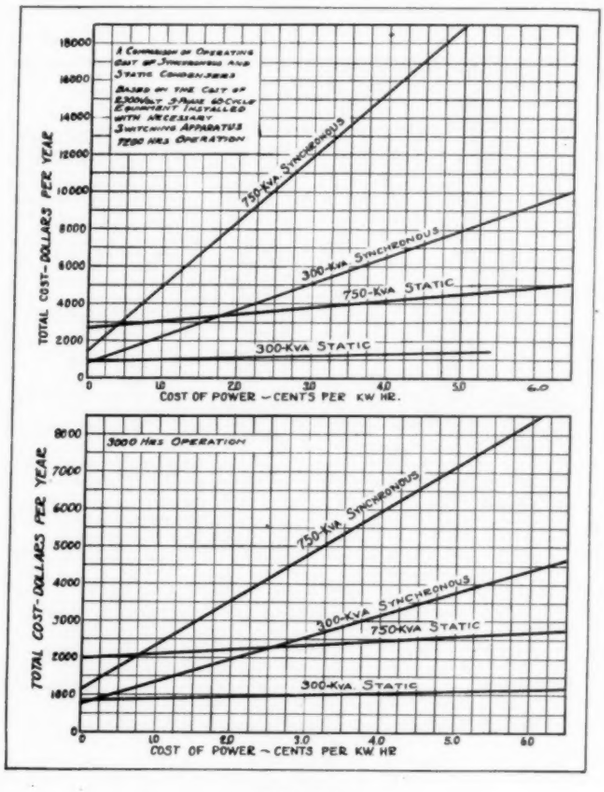
A COMPARISON OF OPERATING COST OF SYNCHRONOUS AND STATIC CONDENSERS
BASED ON THE COST OF 2300 VOLT 3 PHASE 60 CYCLE EQUIPMENT INSTALLED WITH NECESSARY SWITCHING APPARATUS 7200 HRS OPERATION
750-KVA. SYNCHRONOUS
300-KVA SYNCHRONOUS
750-KVA STATIC
300-KVA STATIC
TOTAL COST-DOLLARS PER YEAR
COST OF POWER - CENTS PER KW HR.
3000 HRS OPERATION
750-KVA SYNCHRONOUS
300-KVA SYNCHRONOUS
750-KVA STATIC
300-KVA STATIC
TOTAL COST-DOLLARS PER YEAR
COST OF POWER - CENTS PER KW HR

FIG. 7C

use around steel plants for supplying power to crane motors and rapid reversing auxiliary motors. As compared with the usual rotary converter it has the particular advantages of high overload capacity, low maintenance costs, the ability to isolate the d. c. and a. c. systems from voltage disturbances, and a very useful economical and flexible corrective capacity. This last advantage has been a large factor in permitting the synchronous motor generator set to meet fairly keen competition from the rotary converter. If, however, there is added to the rotary converter the equivalent static condenser capacity which the 80 per cent P. F. synchronous motor possesses, its operating field is materially broadened. The overall operating costs of these two types of equipment exclusive of attendants or maintenance for 3 phase, 60 cycle, 2300 volt service in capacities ranging from 300 to 1500 KW are set forth in some detail in the accompanying curves, Fig. 8-A-B-C. These curves show that in capacities greater than 500 KW for two or three shift operation and with power costing less than 1 per cent per KWMR the rotary converter with static condensers offers the lower operating costs. For one shift operation the synchronous motor generator set is economical up to a power cost of 1.4 cents per KWHr, but only in 300 to 500 KW capacities.

The extremely low power losses in a static condenser, usually averaging less than one-half of one per cent, is of course the big factor in reducing operation costs, although the condensers bear the handicap of a very considerable first cost. As you doubtless know the static condenser is a very simply constructed device. The individual units may consist of a large number of thin metal plates, such as tin-foil or similar material, connected in multiple groups, and each plate insulated from the adjacent plates by thin sheets of insulation—usually a high grade paper—the whole being impregnated with some insulating compound such as wax or oils and enclosed in a tight metal case with suitably insulated terminals brought out for convenient connection. The units are usually of small capacity for convenience in manufacture and assembly, say 1½ to 2 KVA, and are stacked in frames of suitable commercial sizes for final installation. They are usually installed with a high resistance shunted across the buses to provide a discharge path when disconnected from the line. Otherwise they may retain their

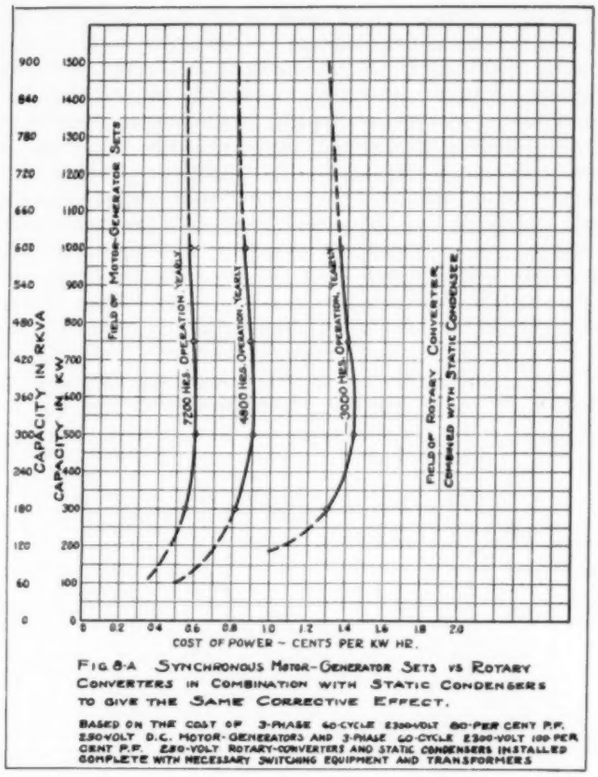
CAPACITY IN KVA
CAPACITY IN KW.
FIELD OF MOTOR-GENERATOR SETS
FIELD OF ROTARY CONVERTER COMBINED WITH STATIC CONDENSER
7200 HRS. OPERATION YEARLY
4800 HRS. OPERATION YEARLY
3000 HRS. OPERATION YEARLY
COST OF POWER - CENTS PER KW HR.

FIG. 8-A SYNCHRONOUS MOTOR-GENERATOR SETS VS ROTARY CONVERTERS IN COMBINATION WITH STATIC CONDENSERS TO GIVE THE SAME CORRECTIVE EFFECT.

BASED ON THE COST OF 3-PHASE 60-CYCLE 2300-VOLT 80-PER CENT P.F. 250-VOLT D.C. MOTOR-GENERATORS AND 3-PHASE 60-CYCLE 2300-VOLT 100 PER CENT P.F. 250-VOLT ROTARY-CONVERTERS AND STATIC CONDENSERS INSTALLED COMPLETE WITH NECESSARY SWITCHING EQUIPMENT AND TRANSFORMERS

FIG. 8A

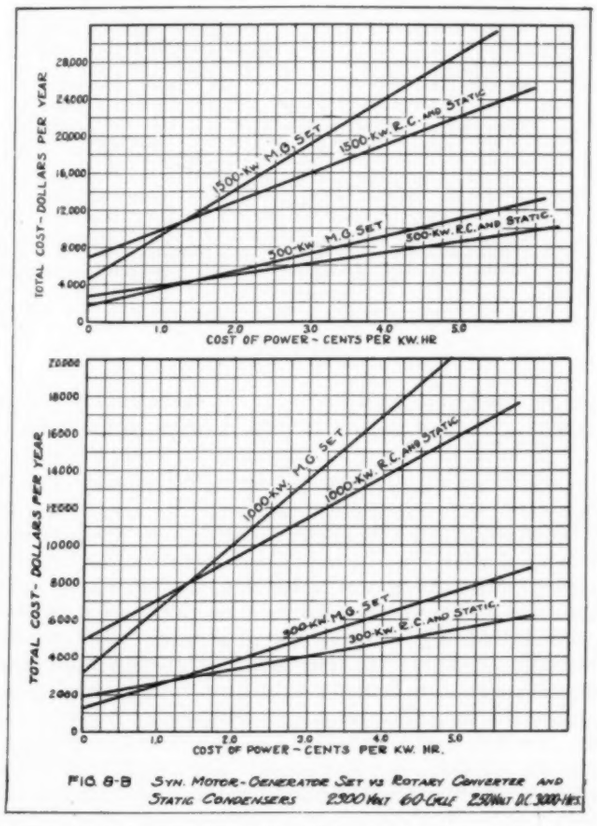
TOTAL COST - DOLLARS PER YEAR
1500-KW. M.G. SET
1500-KW. R.C. AND STATIC
500-KW. M.G. SET
500-KW. R.C. AND STATIC
COST OF POWER - CENTS PER KW.HR
1000-KW. M.G. SET
1000-KW. R.C. AND STATIC
300-KW. M.G. SET
300-KW. R.C. AND STATIC
COST OF POWER - CENTS PER KW. HR.

FIG. 8-B SYN. MOTOR-GENERATOR SET VS ROTARY CONVERTER AND STATIC CONDENSERS 2300 VOLT 60-CYCLE 250 VOLT D.C. 3000-HRS.

FIG. 8B

charge for some four or five hours. The characteristic equation for a static condenser is given as

$$KVA = \frac{E^2\ 2\ \pi\ fc}{1000}$$

from which you will note that the capacity of a condenser varies as the square of the voltage and directly as the frequency. This means that low voltage condensers, say for 220-440-550-volt, are relatively more expensive than those for higher voltages. For reasons of first cost, therefore, you will sometimes find step up transformers offered for use with condensers which are to be applied to low voltage circuits. Transformers of course have losses, introduce another link in the chain and mean one more piece of equipment to maintain. From the attached curves shown in Fig. 9-A-B-C-D it may

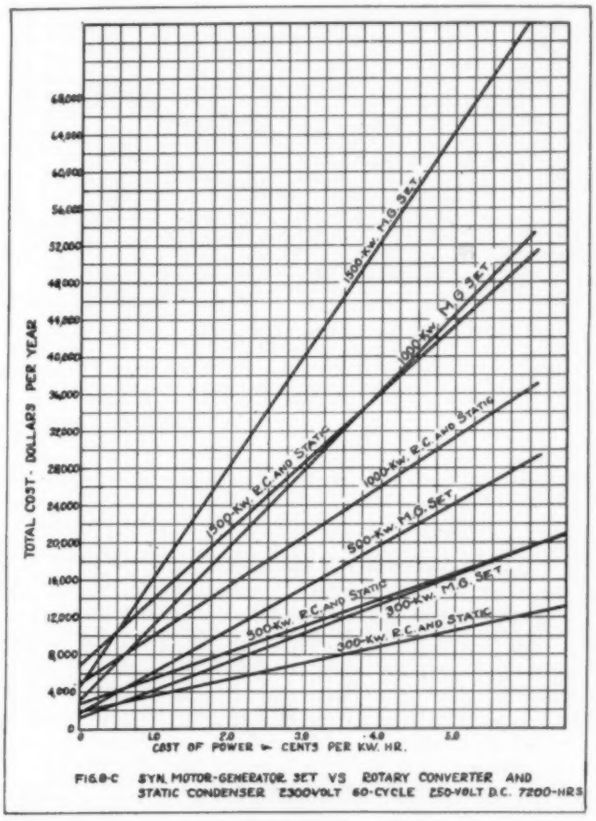
TOTAL COST - DOLLARS PER YEAR
1500-KW. M.G. SET
1500-KW. R.C. AND STATIC
1000-KW. M.G. SET
1000-KW. R.C. AND STATIC
500-KW. M.G. SET
500-KW. R.C. AND STATIC
300-KW. M.G. SET
300-KW. R.C. AND STATIC
COST OF POWER - CENTS PER KW. HR.

FIG. 8-C SYN. MOTOR-GENERATOR SET VS ROTARY CONVERTER AND STATIC CONDENSER 2300 VOLT 60-CYCLE 250-VOLT D.C. 7200-HRS.

FIG. 8C

be seen that the transformer combination is most economical where power costs 1 cent per KWHR or less and where they are connected to the line for some 10 hours per day. For longer operating hours and more expensive power the higher cost low voltage condenser becomes more economical. With a given inducement on the power rate for power factor correction, and a known magnetizing load, these curves will readily indicate to what extent an economical investment may be made in static condensers. The yearly charges include power losses and fixed charges of 15 per cent on the condensers and switching equipment installed complete. Fig. 10 shows total costs for group condenser equipment with switching apparatus for 3 phase, 60 cycle, 2300 volt service. These curves represent average values

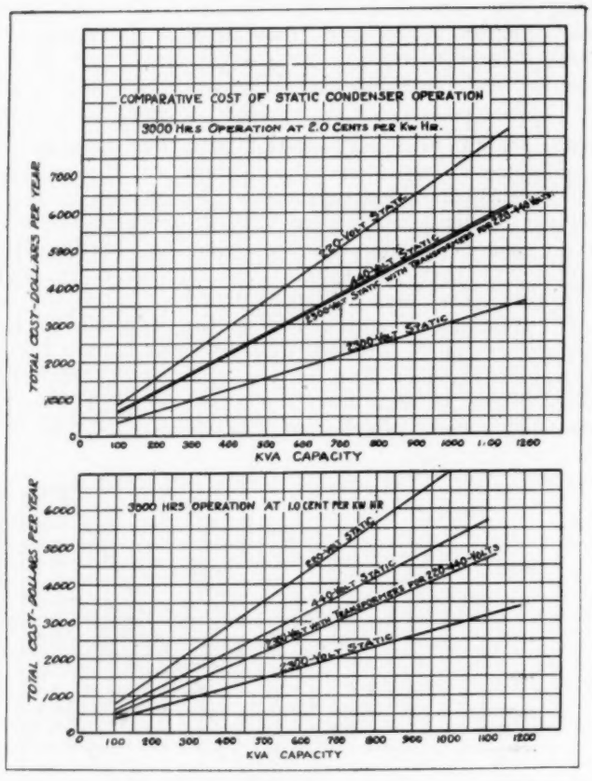

FIG. 9A

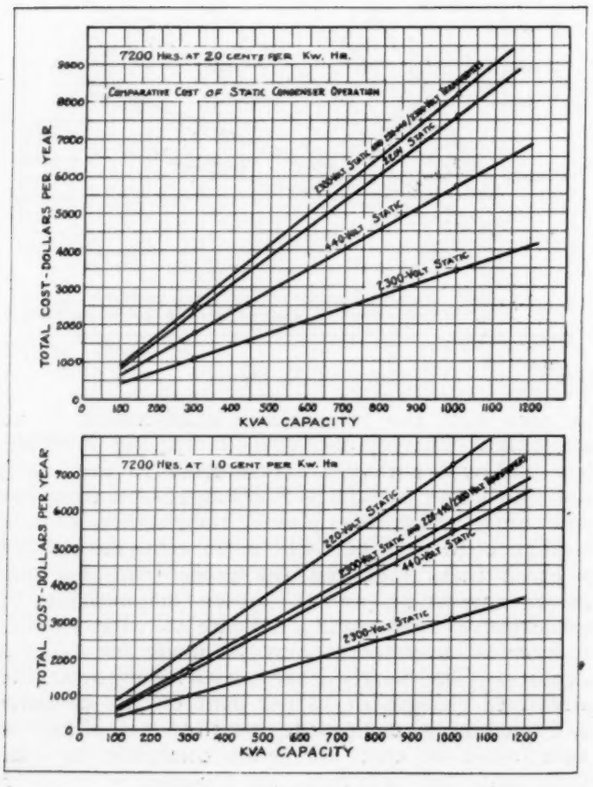

FIG. 9B

and must be used with caution when applied to any particular plant. You will note that none of the condensers considered exceed 2300 volts service. The makers appear to be somewhat reluctant to offer higher voltage condensers except in combination with transformers although I understand some of the condenser designing engineers are confident of handling up to 6600 volts successfully. It is largely a matter of insulation and it would appear reasonable that this can be safely provided for. Since the capacity of a condenser varies directly with the frequency, it follows that the cost of 25 cycle condensers for a given corrective effect varies in the ratio of 60/25 and as a condenser is relatively expensive piece of equipment for even 60 cycle its cost becomes rather excessive for low frequency applications. This, of course, is in line with the greater

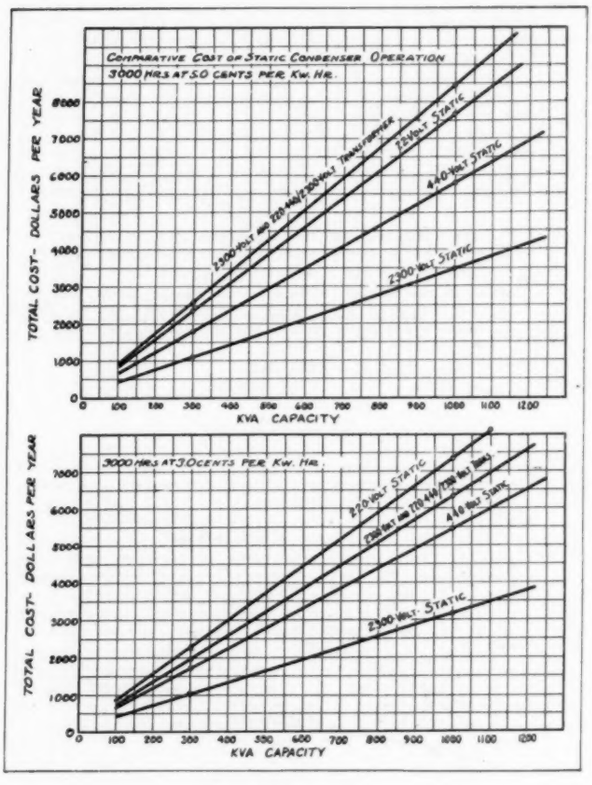
COMPARATIVE COST OF STATIC CONDENSER OPERATION
3000 HRS AT 5.0 CENTS PER KW. HR.
TOTAL COST- DOLLARS PER YEAR
220-VOLT STATIC
440-VOLT STATIC
2300 VOLT STATIC
KVA CAPACITY
3000 HRS AT 3.0 CENTS PER KW. HR.
TOTAL COST- DOLLARS PER YEAR
220 VOLT STATIC
440 VOLT STATIC
2300 VOLT STATIC
KVA CAPACITY

FIG. 9C

weight and increased costs of 25 cycle motors, transformers, etc. For this reason I have not attempted any exhibit of 25 cycle condensers in this paper.

We have made two specific applications of static condensers to induction motors for "group" corrective effect. Each group of induction motors is so arranged that they necessarily operate at a low load factor and consequently with a low average power factor for the group. In one of these groups there is installed a total of seven motors with a rated capacity of 3100 HP. These are relatively high speed motors and have what would be termed a high power factor for induction motors. Connected to the feeder bus in the control station for these seven motors is a bank of static condensers consiting of four frames of 120 KVA each, making a total of 480 KVA. The installation is shown in the photograph, Fig. 11. The operating results are graphically shown in the KVA

demand chart, Fig. 12, which is taken on the feeder for this group of motors while operating on a typical load. They are shown in somewhat greater detail in the series of curves in Figs. 13-A-B-C-D. All these exhibits are designed to show what happens with and without the condensers in circuit. The curves in 13-B clearly show the 480 KVA reduction in magnetizing current on this feeder circuit with the resulting improvement in power factor. These curves also show that the inherent magnetizing current required by these motors is approximately equal to the load current, a by-no-means uncommon condition for a group of induction motors on a swinging load. This condenser bank installed cost in round numbers $9,840. The curve on Fig. 13-D shows the average yearly operating costs for this particular group of motors both with and without the condensers. The condensers must justify their costs in rate saving through power factor improvement and in reduction of line and transformer losses. The net yearly saving for the normal load range on one shift operation is $3,100, for two shift operation it is $6,200. We are satisfied with the investment. In the other group of motors there is installed a total of four motors with a rated capacity of 1200 HP which at present operate at a low load factor, but as in the previous case have a fairly constant demand for magnetizing current. On this group we have installed a bank of static condensers consisting of three frames at 120 KVA each, making a total of 360 KVA. This installation is shown in the photograph, Fig. 14, and the reduction in line magnetizing current is plainly shown in the graphic chart recording the KVA demand of this motor group on a uniform load both with and without the condensers in circuit, Fig. 15. The effect of these two banks of condensers on the 6000 KVA, 2300 volt feeder bus is illustrated by the chart showing KVA demand on this same bus, Fig. 16.

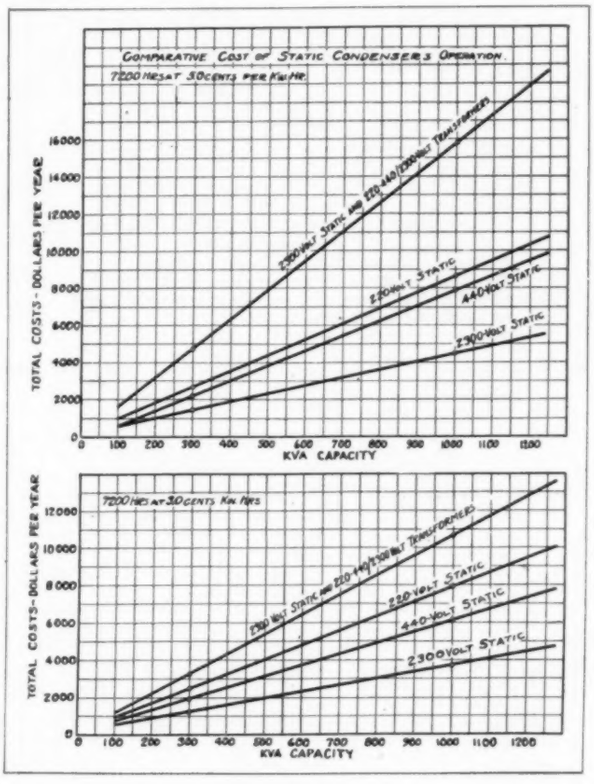
COMPARATIVE COST OF STATIC CONDENSERS OPERATION.
7200 HRS AT 3.0 CENTS PER KW HR.
TOTAL COSTS - DOLLARS PER YEAR
2300 VOLT STATIC AND 220-440/2300 VOLT TRANSFORMER
220 VOLT STATIC
440 VOLT STATIC
2300 VOLT STATIC
KVA CAPACITY
7200 HRS AT 3.0 CENTS KW HRS
TOTAL COSTS - DOLLARS PER YEAR
2300 VOLT STATIC AND 220-440/2300 VOLT TRANSFORMER
220 VOLT STATIC
440 VOLT STATIC
2300 VOLT STATIC
KVA CAPACITY

FIG. 9D

The power contract at this particular plant encourages the continuous use of corrective equipment and as a result these static condensers are left on the line continuously. Their losses are so small it can hardly be identified on the wattmeter, they require no attention, and since installation last September the condensers themselves have given no trouble. Due to an improper assembly of one of the individual oil switches protecting a frame of 120 KVA we experienced one rather vigorous short in

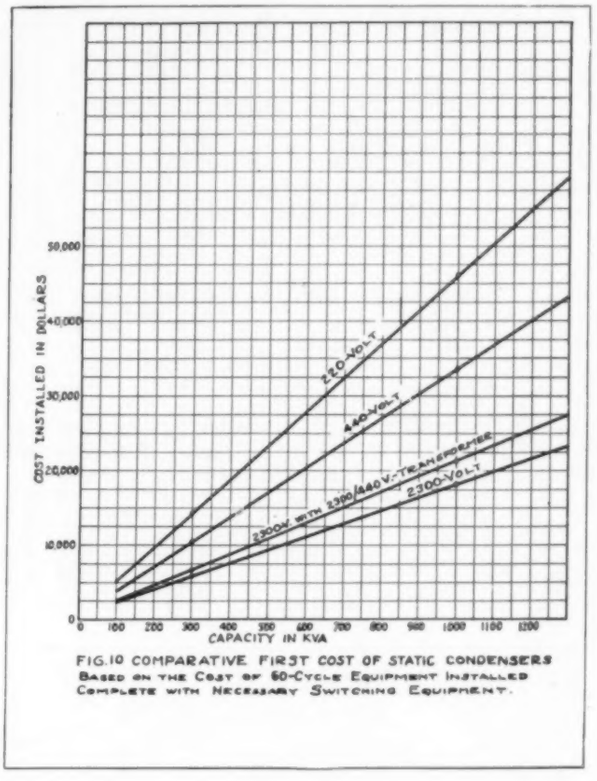

FIG. 10 COMPARATIVE FIRST COST OF STATIC CONDENSERS BASED ON THE COST OF 60-CYCLE EQUIPMENT INSTALLED COMPLETE WITH NECESSARY SWITCHING EQUIPMENT.

FIG. 10

FIG. 11

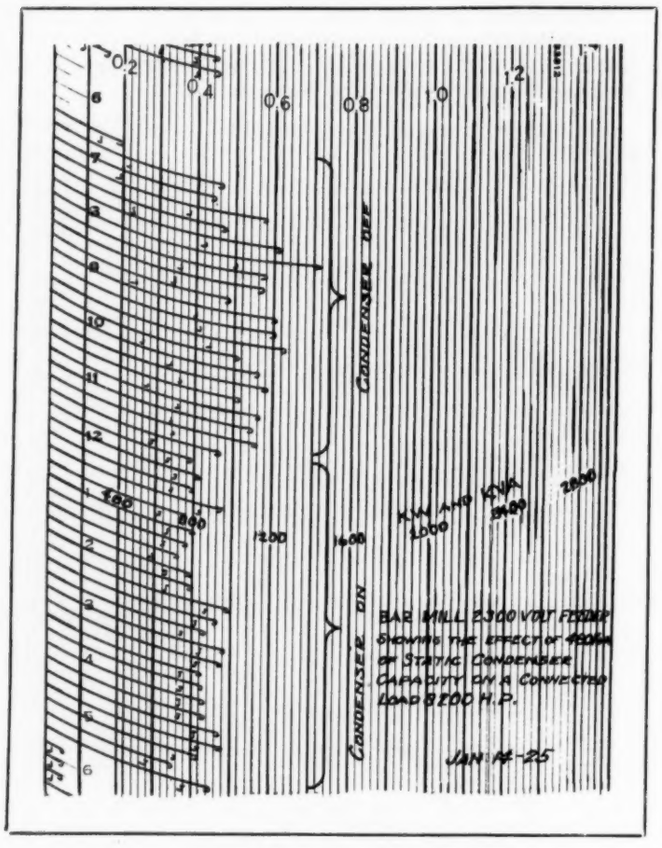

FIG. 12

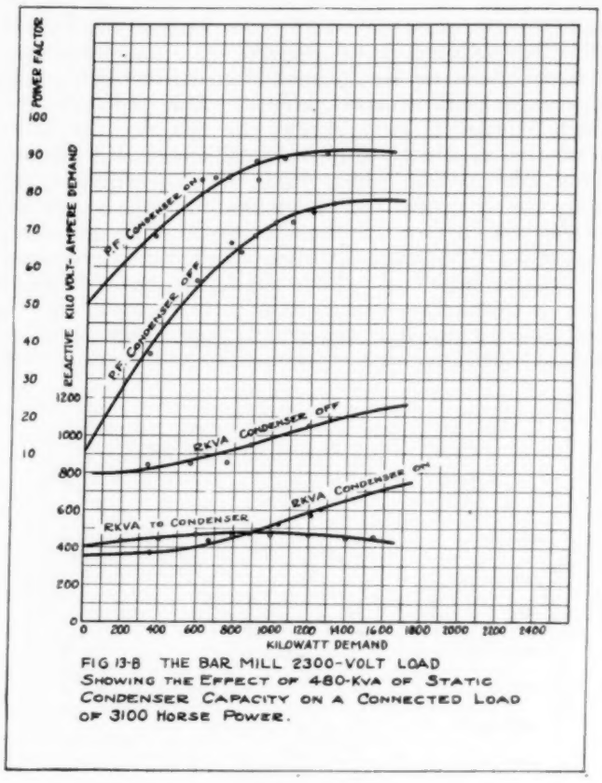

FIG 13-B THE BAR MILL 2300-VOLT LOAD SHOWING THE EFFECT OF 480-KVA OF STATIC CONDENSER CAPACITY ON A CONNECTED LOAD OF 3100 HORSE POWER.

FIG. 13B

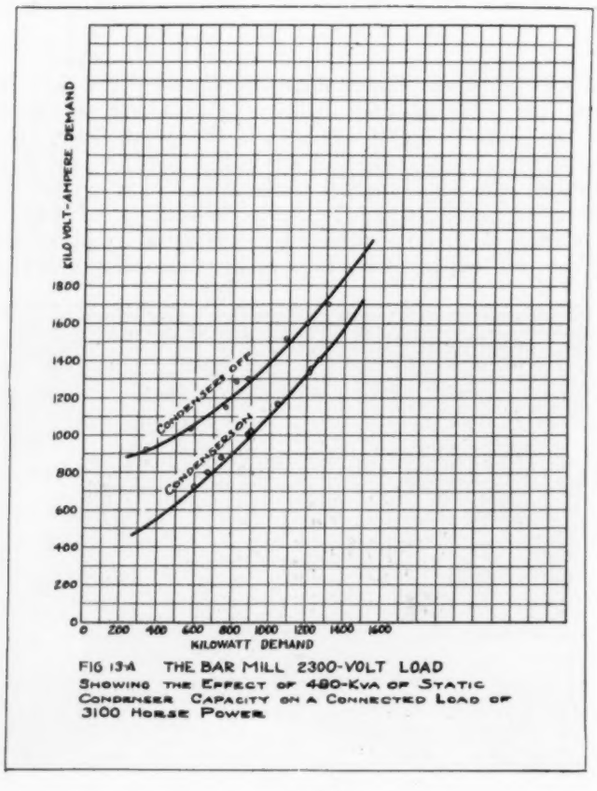

FIG 13-A THE BAR MILL 2300-VOLT LOAD SHOWING THE EFFECT OF 480-KVA OF STATIC CONDENSER CAPACITY ON A CONNECTED LOAD OF 3100 HORSE POWER.

FIG. 13A

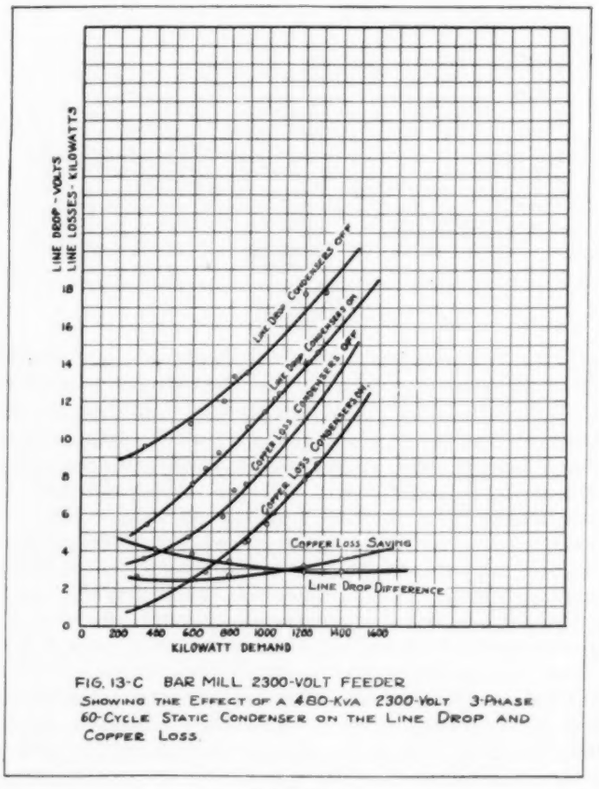

FIG. 13-C BAR MILL 2300-VOLT FEEDER SHOWING THE EFFECT OF A 480-KVA 2300-VOLT 3-PHASE 60-CYCLE STATIC CONDENSER ON THE LINE DROP AND COPPER LOSS

FIG. 13C

the switch itself with minor damage to the switch but no effect on the condensers in that frame or the other three adjoining frames.

When the condensers are first connected to the line the initial current inrush has a tendency to trip the overload release if too closely adjusted. During the instant of switch contact the condensers are charged and if contact is broken and quickly completed by the attendant there is an opportunity for

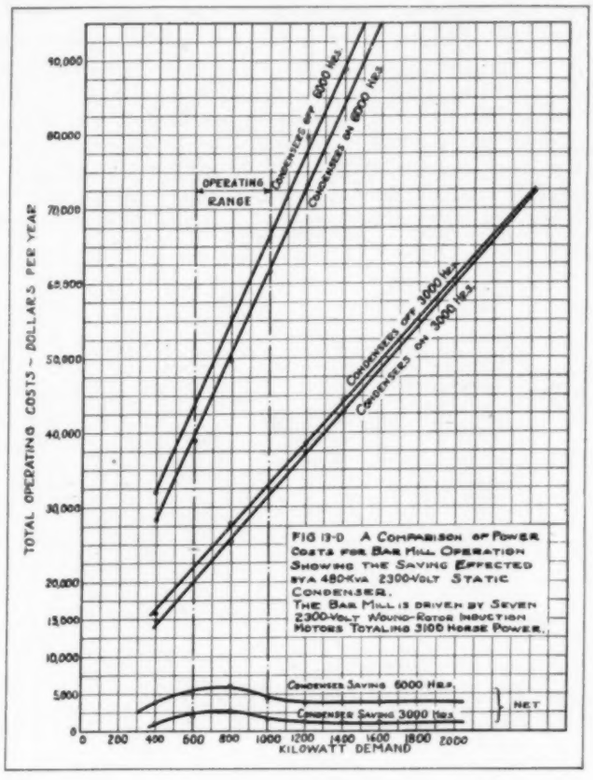

FIG 13-D A COMPARISON OF POWER COSTS FOR BAR MILL OPERATION SHOWING THE SAVING EFFECTED BY A 480-KVA 2300-VOLT STATIC CONDENSER.
THE BAR MILL IS DRIVEN BY SEVEN 2300-VOLT WOUND-ROTOR INDUCTION MOTORS TOTALING 3100 HORSE POWER.

FIG. 13D

the condensers to discharge to the line when not in phase with the line voltage. Aside from the sharp sound usually accompanying a condenser spark discharge there is no evidence of any trouble from this source. The use of an individual oil circuit breaker with over current protection for each frame of 120 KVA is hardly necessary unless the conditions of operation and power supply are such as to justify frequent adjustment of active condenser capacity. The factors which govern the selection of oil switches for motor or feeder duty will likewise govern the selection of the main switch or the individual switch for condenser banks.

During January we maintained an average power factor for the month as determined by watt hour and reactive KVA Hr meters of 89.9 per cent. This was obtained on the usual fluctuating mill load with a 15 min. peak demand of 8505 KW, a load factor of 57.7 per cent, an energy load of 3,600,000 KW Hrs, and an excitation load from the power producer of 1,758,000 RKVA Hrs, for induction motors, transformers, etc. During that same period we operated corrective equipment of sufficient rated capacity to furnish aproximately 850,000 RKVA Hrs, from 1236 KVA in 80 per cent power factor synchronous motors carrying constant excitation current, and some 625,000 RKVA Hrs, from 840 KVA static condensers, or a total from our own equipment of 1,475,000 RKVA Hrs. Without corrective equipment our power factor would have been 74 per cent, with the static condensers alone it would have been 80.9 per cent.

The information so far presented applies to so-called "group" application of static condensers. At first thought it might appear that on account of "diversity factor" there would be some particular merit in a group arrangement.

This merit may or may not exist at a particular plant. If the rate schedule is such that continuous use of corrective equipment is encouraged by the power company and if the normal plant processes require regular operation of practically all inductive apparatus, motors, transformers, etc., a "group" installation of static condensers may not result in any material reduction in first cost or in operating economy. This will be clear when it is recalled that the magnetizing current of inductive apparatus varies only a relatively small amount even though the energy load varies widely. Therefore with a fairly constant magnetizing KVA to correct for it is necessary to apply a fairly fixed value of corrective capacity. The group system, while offering some economy in first cost of condensers, on the other hand requires additional cost for switching apparatus. This can be avoided entirely or greatly reduced if the condensers are applied direct to the individual motor, thus obtaining dual service from

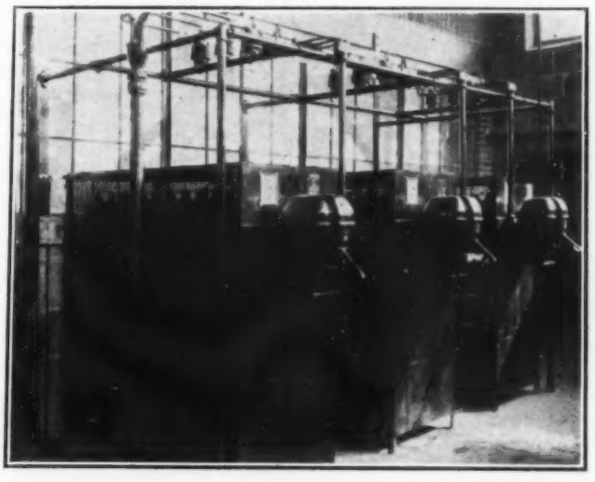

FIG. 14

the motor switch gear. Furthermore the location of individual condensers at the motor when compared with the group installation at the center of distribution provide maximum economy in I^2R losses in the line, and voltage supply at motor terminal.

In considering this phase of static condenser application the average present day cost figures of 60 cycle condensers for 220-440 and 2300 volt operation and in combination with transformers for 220-440 volt service are shown in figure 17. The manufacturing processes involved in producing condensers are somewhat tedious and exacting, but it does not seem unreasonable to expect substantial

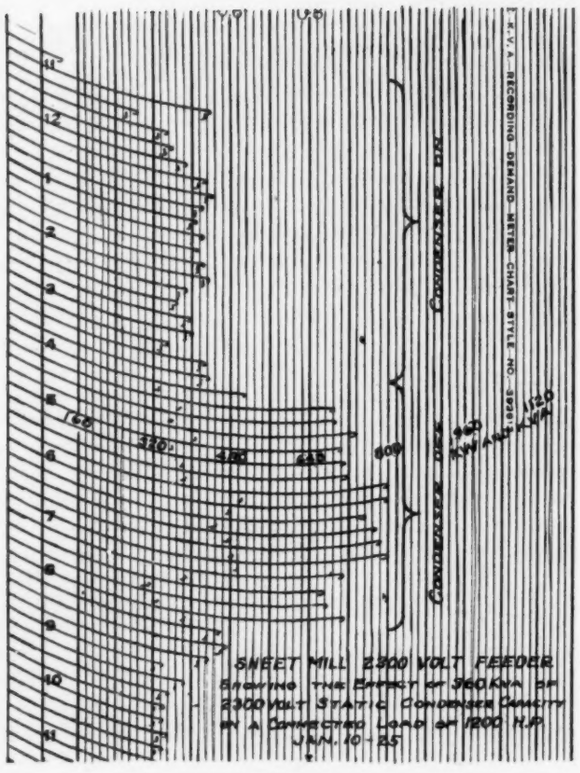
SWEET MILL 2300 VOLT FEEDER
Showing the Effect of 360 Kva of
2300 Volt Static Condenser Capacity
on a Connected Load of 1200 H.P.
JAN. 10-25

FIG. 15

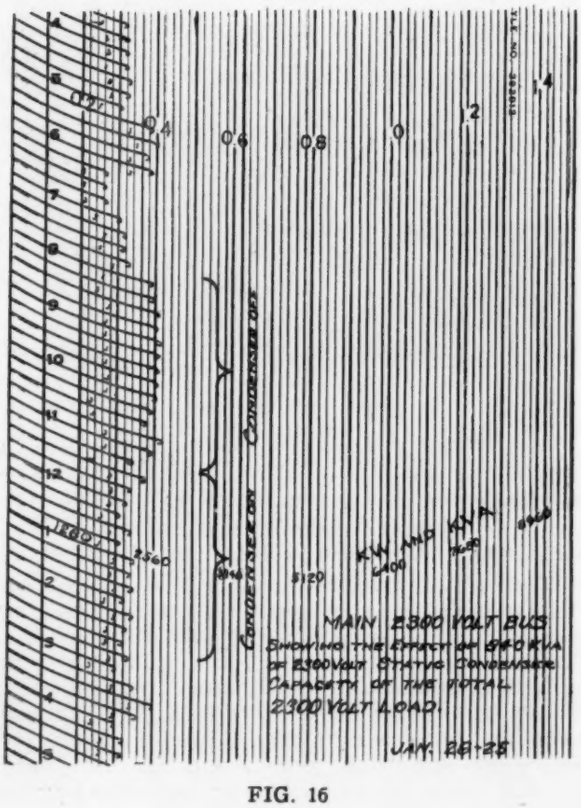
MAIN 2300 VOLT BUS
Showing the Effect of 540 Kva
of 2300 Volt Static Condenser
Capacity of the Total
2300 Volt Load.
JAN. 26-25

FIG. 16

reduction in these figures as volume of production increases and experience and skill advance.

In every steel plant using numbers of induction motors there will usually exist a few applications which particularly favor the local application of static condensers. For instance, those motors at the end of a long feeder circuit containing insufficient copper, or the squirrel cage motor which is burdened with a starting load about equal to or sometimes greater than its inherent capacity, or those motors installed to drive a machine with high value infrequent peak loads and a relatively light average load. The application of condensers direct to the motor terminals will frequently overcome the effect of insufficient copper, of low voltage, or low average power factor and enable the motor to develop its maximum power, give snappier starting torque or eliminate a troublesome source of low power factor

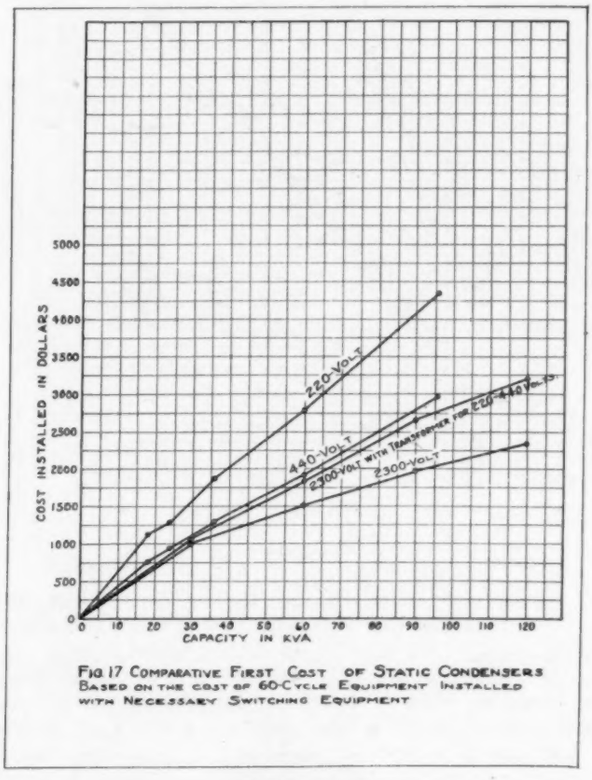

FIG 17 COMPARATIVE FIRST COST OF STATIC CONDENSERS BASED ON THE COST OF 60-CYCLE EQUIPMENT INSTALLED WITH NECESSARY SWITCHING EQUIPMENT

FIG. 17

on the plant system. The installation of a static condenser of sufficient capacity to provide for the full load magnetizing current of any given motor will usually result in some excess capacity at lesser loads which will be found very useful. When properly protected in a suitable enclosing case, such as appears in Fig. 18, there should be no difficulty in mounting a small installation adjacent to the starting equipment or motor. When once installed it should require but little further attention and would automatically become effective whenever the motor was running if connected beyond the starting box. We are now giving this plan considerable thought and investigation, but results have not progressed to a point which would justify presenting them here tonight.

In considering the application of static condensers to individual induction motors there immediately comes to mind the recently arrived "synchronous induction" motor with its inherent ability to not alone operate at unity power factor, but if desired can be designed or adjusted to provide leading power factor and thus correct for low power factor imposed by some other inductive load. I feel that this paper would be incomplete to you men if some attempt was not made to evaluate that motor in comparison with our old friend, the squirrel cage induction motor.

From the published reports regarding the construction and performance of the "synchronous induction" motor I should say that this motor is essentially a self excited synchronous motor with excitation for unity power factor or over excited for leading power factor as desired. It has a rotating armature with the usual slip rings for collecting line current, an auxiliary field winding for start-

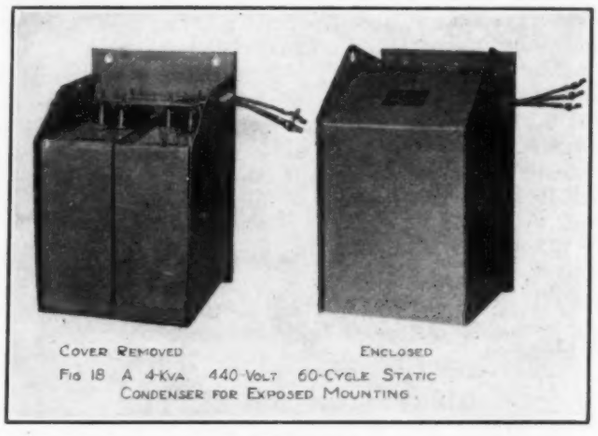

FIG 18 A 4-KVA 440-VOLT 60-CYCLE STATIC CONDENSER FOR EXPOSED MOUNTING.

FIG. 18

ing, a stationary field winding receiving its synchronous excitation from a low voltage exciter with its coils embedded in the same slots as the A. C. windings and with its commutator carried on the same shaft. It starts as an induction motor with starting resistance inserted in the auxiliary and field windings, runs as a synchronous motor until pulled out of step at some 150 per cent to 180 per cent load and then operates as an induction motor at the usual induction motor power factor until the load is decreased to the synchronous motor range or if the load continues to increase it reaches a "breakdown" point similar to an induction motor.

In a recent publication issued by the manufacturer of the "Synchronous-Induction Motor," claims are made for efficiencies even higher than those usually found in corresponding sizes of standard squirrel cage induction motors. If these high efficiencies can actually be realized by the user in competitive motors, then the "Synchronous-Induction Motor" will show lower yearly operating costs, under the conditions indicated by Figure 19, than the squirrel cage induction motor in combination with static condensers. The prospective user would then have to make a choice based on characteristics of simplicity, ruggedness, maintenance, etc., rather than operating costs alone.

Being supplied with four separate windings, a commutator, a set of slip rings and two sets of brush holders and brushes it is necessarily handicapped somewhat in cost and efficiency as compared with the single winding squirrel cage induction motor with its two bearings as the only wearing parts. However if we add to the squirrel cage induction motor sufficient static condenser capacity to provide an equivalent power factor correction the first cost is in favor of the "synchronous induction" motor, except perhaps in the smaller sizes, as shown by the curves in Fig. 19. On the basis of yearly operating costs exclusive of maintenance or repairs and using average published efficiency values as obtained by various independent observers, the

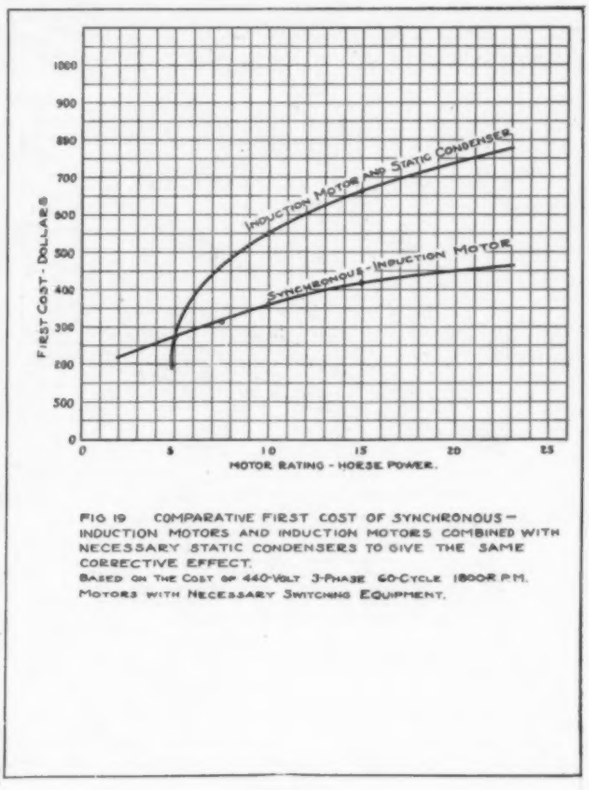

FIG 19 COMPARATIVE FIRST COST OF SYNCHRONOUS-INDUCTION MOTORS AND INDUCTION MOTORS COMBINED WITH NECESSARY STATIC CONDENSERS TO GIVE THE SAME CORRECTIVE EFFECT.
BASED ON THE COST OF 440-VOLT 3-PHASE 60-CYCLE 1800 R.P.M. MOTORS WITH NECESSARY SWITCHING EQUIPMENT.

FIG. 19

squirrel cage motor in combination with static condensers gives the lower yearly operating costs as shown by Fig. 20.

It would be useless to attempt a comparison of anticipated operating results for the two equipments without more extensive experience than is now available to the writer, but it is hoped that the information presented will be of some assistance in making a selection.

There is one phase of static condenser operation which apparently has caused trouble in certain installations although we have so far escaped its effects and that is an approach towards a condition of electric resonance, due to the presence of harmonic currents in the circuit. This condition may exist as you will recall when in the equation:

$$I = \frac{E}{\sqrt{R^2 + (WL - \frac{1}{WC})^2}}, \quad WL = \frac{1}{WC}$$

for under that condition the current will be limited only by the value of "R," which would usually be sufficiently small to permit excessive current flow. This critical condition would develop as the frequency approaches

$$f = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$$

"L" and "C" being the reactance and capacity existing in the circuit from the point where the condensers are installed back to the point where the harmonics originate, be that at the power house, transmission line, or adjacent apparatus. Our condensers are connected directly to the 2300-volt sub-station bus without external reactance, other than that which exists in the feeders, station transformers, transmission line, etc., back to the power house generator. Thus far we have experienced no known effects from harmonics. I cannot say

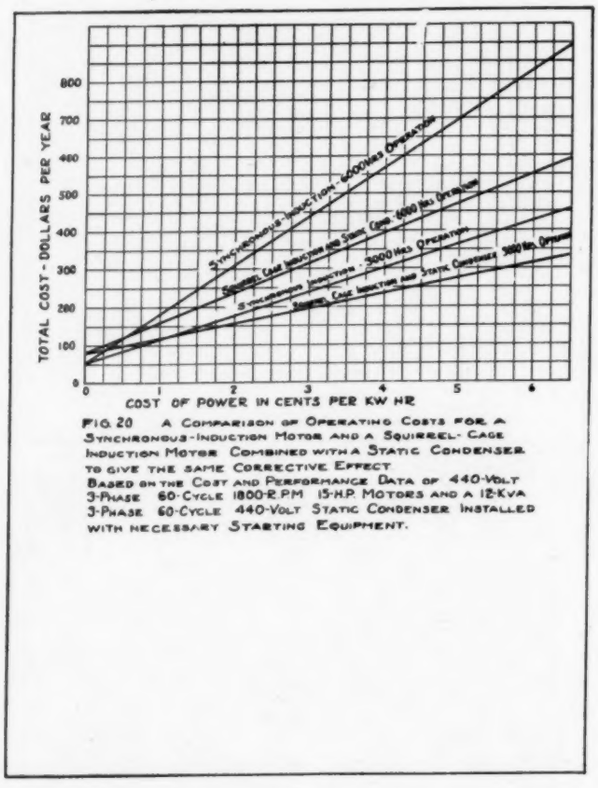

FIG. 20 A COMPARISON OF OPERATING COSTS FOR A SYNCHRONOUS-INDUCTION MOTOR AND A SQUIRREL-CAGE INDUCTION MOTOR COMBINED WITH A STATIC CONDENSER TO GIVE THE SAME CORRECTIVE EFFECT. BASED ON THE COST AND PERFORMANCE DATA OF 440-VOLT 3-PHASE 60-CYCLE 1800-R.P.M. 15-H.P. MOTORS AND A 12-KVA 3-PHASE 60-CYCLE 440-VOLT STATIC CONDENSER INSTALLED WITH NECESSARY STARTING EQUIPMENT.

FIG. 20

whether that is due to the absense of harmonics in our voltage wave or there is sufficient total circuit reactance to damp out their effect if they do exist. If it is the total circuit reactance, which is effective, then it would seem reasonable that most installations using power generated in a large modern power house, located some distance away and fed from a transmission line equipped with step up and step down transformers, would be free from resonance disturbances in the condenser, which might be installed. For, in such a system, the total circuit reactance can easily reach 15-20%, which value is said to provide assurance against resonance. If, on the other hand, it is the local circuit reactance which is effective, there seems to be a greater chance of resonance occurring. As an illustration in our bank of 480 KVA installation the line reactance is some .0000907 henrys, while the condenser capacity is .00024 farads, both at 60 cycles.

Substituting these values in the above critical frequency equation, we have:

$$f = \frac{1}{2\pi} \sqrt{\frac{1}{.000097 \times .00024}} = \frac{6780}{2\pi} = 1080\pi$$

Since the fundamental frequence is 60 this value would represent the eighteenth harmonic. Either a large reactance or greater capacity would approach closer to a noticeable resonance condition. I hope that additional information and experience on this possible source of trouble will be presented here tonight, for it is of considerable importance in any prospective condenser installation.

In conclusion, I feel that it is safe to say that our experience thus far with the static condenser has been successful from both an operating and economic standpoint. In the electric circuit there are but three factors with which we can work, and those three are resistance, reactance, and capacitance. The first two have long been available in commercial form, and we are familiar with their use. I believe that we are going to find the third one just as useful and necessary as the first two and that electrical men of the steel mills in common with other users of inductive equipment, will learn to apply the static condenser as readily and efficiently as he has learned to apply the resistor or reactor.

In closing, I wish to take this opportunity to thank those who have supplied me with necessary data and Mr. W. S. Fields, in particular, for the very considerable calculations he has performed.

DISCUSSION BY LETTER

H. Weichsel*: Mr. Dudley discusses in this paper operating results which he observed on 60 cycle static condenser installations. These installations consisted of static condensers of 2,200 volts and were connected across the secondary of transformers in all cases where the line voltage differed from 2,200 volts. The paper discloses in a very clear manner the economic advantages which result from power factor correction in general and from the use of static condensers in particular.

For completeness' sake he also refers to what he calls the recently devised "synchronous induction motor." The company with which I am connected manufactures the only "synchronous induction motor" on the market—the Fynn-Weichsel motor. It will probably be of interest to the reader to have more detailed discussions on some of the mechanical and electrical design features as well as on some of the economical questions which relate to this new type of machine.

Mr. Dudley's description of the mechanical design of this novel motor is correct in general. His statement regarding the "four separate windings" in this machine may, however, be complemented as follows:

This machine has a polyphase winding on the stator as well as on the rotor. The rotor also carries a small d. c. winding. The polyphase stator

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winding is in all cases a two-phase winding. The number of phases in the polyphase rotor winding, on the other hand, depends naturally on the number of phases in the supply circuit, which is generally three-phase. One of the phases on the stator (secondary member) is used for starting only, while the other phase is used for starting and running. The former phase usually is called the "auxiliary" winding, while the latter is called the "field" winding. The use of these two different names for the phases of the two-phase stator winding no doubt caused Mr. Dudley to speak of four windings, i. e., he figured a polyphase rotor winding, a d. c. winding, an auxiliary stator winding, and a field stator winding. But when each phase of the two-phase secondary winding is called a separate winding, then with the same justification each phase of a three-phase primary winding of this new motor as well as of any induction motor must be considered as one winding.

With this manner of counting the windings, a standard three-phase induction motor with a three phase wound rotor would, therefore, have six windings and the same number of windings would also be found for a three-phase Fynn-Weichsel motor.

In Fig 19, plate 22, Mr. Dudley compares the "first cost" of this new type of motor with that of a squirrel cage motor of equal horse-power and speed ratings but the latter equipped with a 440 volt condenser of suitable capacity to give the combination of the squirrel cage motor and the condenser the same leading power factor which the Fynn-Weichsel motor has inherently. The plot refers to 1,800 RPM machines up to 25 HP ratings.

A more detailed study of this subject shows that the cost difference between these two kinds of equipment when expressed in per cent increases noticeably with increasing horse-power capacity. The reason for this will be found in the fact that the cost of the condensers increases nearly proportional to their k. v. a. capacity, and as the required k. v. a. capacity is nearly proportional to the motor horse-power capacity, it follows that there must be added to the cost of the squirrel cage motors an amount representing the cost of the condensers which is nearly proportional to the horse-power capacity of the machine.

The price of the Fynn-Weichsel motors, on the other hand, increases much slower than the horse-power capacity. It is clear, therefore, that the relation $\frac{\text{first cost of Flynn-Weichsel motors}}{\text{first cost of squirrel cage motors}}$ becomes more favorable the larger the horse-power capacity.

In many cases found in practice, the first cost of the Fynn-Weichsel motors is 50 per cent or less than that of an equipment of squirrel cage motors provided with 440 volt condensers. However, the largest percentage of industrial plants operate on 220 volts and not 440. In 220 volt circuits, the cost of condensers for equal capacity is practically twice that of condensers for 440 volt circuits.

The above figures for the first cost of the Fynn-Weichsel motors in comparison with the first cost of squirrel cage motors plus condensers become, therefore, still more favorable for 220 volt installations than they are for 440 volt installations.

There is further frequently an additional saving in the first cost of a Fynn-Weichsel motor installation which is caused by the superior starting characteristics of this type of motor over the characteristics generally found in squirrel cage motors. Frequently the size of a squirrel cage motor for a certain service is governed by the starting torque requirements rather than the running load on the motor. In all these cases a Fynn-Weichsel motor can be selected of just sufficient size to handle the running load satisfactorily as the starting load of this type of machine is very excellent and far superior to that of a squirrel cage motor. In several actual installations, this superior starting characteristic has resulted in an appreciable saving in the first cost of the machine.

In Fig. 20 Mr. Dudley gives a comparison of operating costs for a synchronous induction motor and a squirrel cage induction motor combined with a static condenser to give the same corrective effect. These curves are based on 440 volt, 3-phase condensers.

I have tried in vain to check these data and have come to the conclusion that some mistake must have been made in these figures. There is given below a calculation for the same example which was selected by Mr. Dudley. This calculation is based on the cost figures given in Mr. Dudley's Fig. 15. As efficiency for the Fynn-Weichsel motor, the manufacturer's guarantee of 88 per cent is used. As efficiency for a corresponding squirrel cage motor, 89 per cent has been used, which is a value specified by the Navy Yard for squirrel cage motors of this capacity.

An assumption of a working schedule of 3,000 hours and an energy rate of 5 cents per kw. hour is used for figuring the operating expenses. Also, the losses for the condensers have been assumed as 5 watts for each k. v. a. condenser capacity. The fixed charge for investment is taken at 15 per cent, in accordance with Mr. Dudley's recommendations in his paper.

First cost of Fynn-Weichsel motor, 15 HP., 4 pole.....$420	
Fixed charge on investment = .15 x 420 = ...	$ 63.00
Operating cost = $\frac{15 \times .746 \times 3000 \times .05}{.88}$ =	1905.40
Total yearly cost.....	$1968.40
First cost of squirrel cage motor and 440 volt condenser.....$660	
Fixed charge on investment = .15 x 660 = ...	$ 99.00
Operating cost of motor = $\frac{15 \times .746 \times 3000 \times .05}{.89}$ =	1884.00
Operating cost of 12 k. v. a. condenser= 12 x 3000 x .05 x .005=	9.00
Total yearly cost.....	$1992.00
Difference in yearly operating cost.....	$ 23.60

The gain found in the above calculation in favor of the Fynn-Weichsel motor is based on an installation with 440 volt condensers connected across the line, but as the condenser cost in a 220 volt installation is materially higher, it follows that a 220 volt installation would show still more favorable results.

Mr. Dudley properly points out in his paper that low voltage (220 or 440 volts) condensers are not yet in general use and that preference is given to connecting a step-up transformer (440/2200 volts) between the line and the condenser. This arrangement is the one which is most generally used and is also the one which is employed in the actual installations which Mr. Dudley describes in his paper. There are doubtlessly many advantages in this particular manner of using static condensers, but naturally this arrangement requires, due to the use of transformers, a somewhat larger energy loss, which usually runs about 3 1/2 k. w. for every 100 k. v. a. condenser capacity. This difference in energy loss would increase the cost for the energy loss in the condenser equipment to $54 a year over the value shown in the above table.

The relations shown in the beginning become more favorable the larger the units. A few examples based on actual machines will be instructive. A 75 HP, 6 pole, 60 cycle Fynn-Weichsel motor showed on test 1 per cent higher full load efficiency than an average squirrel cage motor of equal rating. The difference in energy (k. w.) draw required for operating the Fynn-Weichsel motor equipment and for operating the straight squirrel cage motor is given by the formula:

$$\frac{y_1 - y_2}{y_1 y_2} \text{ HP} \times .746$$

Where y_1 = efficiency of Fynn-Weichsel motor.
Where y_2 = efficiency of the squirrel cage motor.

In our case the difference in cost for energy when operating 3000 hours a year and with an energy rate of 5 cents per k. w. hour amounts to .0123x75 x .746 x .05 x 3000 = $105.

In order to obtain the same power factor correction from the squirrel cage motor as from the Fynn-Weichsel motor, a 70 k. v. a. condenser is required. If this condenser is of the 440 volt type, the cost for its energy losses is 70 x 3000 x .05 x .005 = $52.50, making the total gain for energy cost 105 + 52.50 = $157.50.

The difference in the first costs of these two different equipments is $1507. Therefore, the difference in fixed charges is .15 x 1507 = $226. The total yearly saving in favor of the Fynn-Weichsel motor is, therefore, $226 plus $157.50 = $383.50.

If a 220 volt distribution is used and the condensers are connected directly across the line, the difference in first cost between the Fynn-Weichsel motor equipment and the squirrel cage motor plus condenser equipment will be $3607 with a corresponding difference in fixed charges of $543. The yearly saving would be $700.50.

When the general practice is followed, using a 2200 volt condenser with a corresponding step-up transformer, the cost for operating these condensers amounts to $367. The fixed charge for the condenser equipment is $23 less when a transformer is used than when 440 volt condensers are used, making this charge $203. The total yearly saving in favor of the Fynn-Weichsel motor in this case will be $367 plus $203 plus $105 = $675.

In a similar manner the costs have been calculated for a 100 HP, 600 RPM and a 100 HP, 720 RPM unit. The results of this calculation are tabulated below.

DIFFERENCE IN COST IN DOLLARS

HP	RPM	First Cost	Fixed Charges per year	Power bill per year	Total per year	Combination
15	1800	240	36	12.50	23.50	B
75	1200	3607	543	158	701	A
		1507	226	158	384	B
		1357	203	470	673	C
100	720	4415	633	67	730	A
		1845	277	67	344	B
		1509	226	475	701	C
100	600	4148	620	203	823	A
		1628	244	203	447	B
		1442	216	610	826	C

Combination A = 220 volts supply and 220 volt condenser.
Combination B = 440 volts supply and 440 volt condenser.
Combination C = any supply voltage and transformer for 2200 volt condensers.

A saving is revealed in favor of the Fynn-Weichsel motors in all the cases shown in the above table.

Readers who desire to familiarize themselves further with the characteristics of the Fynn-Weichsel motor are referred to the following publications:

Iron and Steel Engineer, April, 1924, "The Motor That Corrects Power Factor."

Proceedings of the Franklin Institute, May, 1925, "The Fynn-Weichsel Motor."

Midwinter Convention of the A. I. E. E., February 9-12, 1925, "A New General-Purpose Alternating-Current Motor."

Besides the operating costs and first costs discussed above, the question of maintenance must be considered. It is an established fact that if accidental burn-outs on the windings and condensers are disregarded, a large percentage of the maintenance required for a squirrel cage motor installation is to be found in the contacts of the compensators. The contacts of the compensators naturally wear and burn away and require attendance at certain intervals. Against this we have in the Fynn-Weichsel motor a natural wear of the brushes and current collecting members. An inspection of a large number of motors of this new type which have been in operation for over a year has shown that no replacal of the wearing parts was necessary. This is in full harmony with a statement made by Mr. A. E. Clayton in his booklet entitled "Subject of Power Factor Correction," in which he stated: "The collection of current from slip rings and commutators has passed satisfactorily through the ailments associated with infancy and there is no reason for lack of confidence in a machine which possesses a commutator. Even in cases where reliability is particularly important, as in pit shaft winding, one often finds fly wheel converters and Ward-Leonard control used instead of the simple induction motor."

It may be added that the commutator of the Fynn-Weichsel motor handles d. c. potentials of the order of magnitude of 30 volts maximum only and, therefore, must have a very high degree of reliability. It is further justifiable to assume that the possibility of failure of the current collecting devices is certainly not more and probably less than the possibility of a breakdown inside of the condensers, where acres of fine metal sheeting carrying

high potentials are separated by a correspondingly large area of thin layers of insulation.

Besides the means for power factor correction discussed in Mr. Dudley's paper, there are several other means known by which the desired corrections may be achieved. Each one of these means no doubt has its own field of usefulness and it is an engineering as well as an economical problem to decide for the individual installations which of the means is most suitable. In arriving at a decision not only the questions discussed above must be considered but also many others, such as voltage regulation under different load conditions, floor space required for the different equipments, losses in distribution wiring, etc.

R. W. Dudley: At the time the data for this paper was worked up there were no guaranteed figures for the full-load efficiency and power factor of a 4-pole, 15 HP. Fynn-Weichsel motor at hand. We did have several reports showing the performance curves for this motor, so average values of full-load efficiency and power factor were calculated from these curves. The data presented in these reports are as follows:

Tested by	Published in	Full-load Eff. Per cent.	Full-load P. F. Per cent.
Commonwealth Edison Co.	Both in "Some Recent Comprehensive Tests on the Fynn-Weichsel Motor" Wagner Electric Corporation.	86	93
Philadelphia Elec. Co.		83	92
H. E. Dyche, U. of Pittsburgh	Discussion of "The Motor That Corrects Power Factor" by H. Weichsel in the Iron and Steel Engineer, April, 1924	82	94
Price and Kelso, U. of Wis.	"Tests on the Fynn-Weichsel Motor" by Royce E. Johnston, Wagner Electric Corporation	86	88
Union Gas & Elec. Co., Cincinnati	Not published	83	83
	Average of tests	84	90

Calculated on this basis, the yearly costs for the synchronous-induction motor for 3,000 hrs. operation at an energy rate of 5 cents per KW. hour are as follows, allowing 5 per cent of installing and 15 per cent for fixed charges on the investment.

First cost of Synchronous Induction Motor, 15-HP, 4-Pole	$ 420.00
Installation @ 5 per cent	21.00
Cost installed	$ 441.00
Fixed charge on investment equals .15 x 441	$ 66.15
Operating cost equals $\frac{15 \times .746 \times 3000 \times .05}{84}$	1998.21
Total yearly cost	$2064.36
First cost of Squirrel Cage Motor and 440-Volt Static Condenser	$ 663.60
Installation @ 5 per cent	33.18
	$ 696.78
Fixed charge on investment	$ 104.52
Operating cost of motors equals $\frac{15 \times .746 \times 3000 \times .05}{.90}$	1865.00
Operating cost of 12-KVA Condenser equals 12 x 3000 x .05 x .005	9.00
Total yearly cost	$1978.52
Difference in yearly operating cost equals $2064.36-$1978.52	$ 85.84

The term "operating costs," as used in connection with figure 20 is misleading. These curves show the cost of the losses in the motor and condenser plus the fixed charges rather than the cost of the total power input to the motors plus the fixed charges. The difference in operating costs, however, is the same whether we consider the cost of the total power to the motors, or the losses only.

It might also be pointed out that the installation described is connected directly to the 2300-volt bus and not through step-up transformers.

*Fuel Application—The Essential Factor in Furnace Design**

By E. J. EVANS†

ONE of the greatest dangers that confronts the business executive today is the possibility that he may fail to correctly diagnose the trend of industry, and be unable to foresee with accuracy the effects of scientific and engineering developments on present practices. The whole patch of civilization is littered with the carcasses of enterprises that met ruin and death through the inability and neglect of managements to visualize, in advance, the changes that were coming. In order to be a lasting success at the present time, it is essential that we be informed, not only concerning the developments in the industry of which we are a part, but that we have a working knowledge of what is going on in other lines of activity, kindred in nature.

The present speed of life has been accelerated to such a furious pace that things new today, literally speaking, are obsolete tomorrow. Ages ago when the Chinese discovered a way to manufacture silk they suc-

*Presented before Birmingham Section, A.I.&S.E.E.

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ceeded in keeping the method secret for 2,000 years. Even no longer ago than the commencement of the nineteenth century, the progress of science had only reached such a rate of movement that years intervened between revolutionary discoveries. Twenty years lapsed after Watts' condensing steam engine until Morse gave us the telegraph. Another twenty years passed before Bessemer perfected his process, which revolutionized the steel industry, and a similar lapse of time occurred before we found a way to substitute gas light for the lamp that burned sperm oil.

Then along came the telephone and the electric light, and immediately things began to happen and the pace was increased. Now we count that day lost during which no record is broken. Each time we add up the figures we find a new total has been established, and this is true all along the line from the $900,000,000 we spend annually for soda water down to the 13,000 total for suicides in the United States last year. The great trouble is that we have gone forward so fast in recent times that we could not keep our rearward lines of communication fully open. As a result our lives are full of inconsistencies. Waste is all about us. We have a surplus of workers in one industry and a deficit in another, with the resultant, economic loss.

The difficulty is that we are more skillful in discovering new truths than in utilizing them. A canvasser tried to sell a farmer an encyclopedia of agriculture and dwelt at length on the great variety and value of the information the book contained. He delivered quite an oration about plants, soil and animals, and placed much emphasis on when to plant and how to cultivate. The farmer listened with interest and then shook his head hopelessly, saying: "The book wouldn't be of any use to me 'cause I ain't farmin' even as well as I know how now."

So it is throughout all of our industrial life today. We have many times more information available than we attempt in any way to utilize.

It is hard for us to realize that for only a few centuries, fire has to any extent been under control of man for other uses than the very primitive ones of keeping him warm and cooking his food. Except for these two purposes, fire was a fearful element in man's life, something distinctly to be avoided and to be prevented. In fact, it is undoubtedly true that for a very long period in the history of the human race, fire was merely a devastating and harmful force, and the use to which it was put was infinitesimal compared to the injury it wrought.

It was only in the days of Watt that fire came into its own as the great benefactor of the human race through its application for making steam. Then followed the gradual stages of progress made possible by development of mechanical devices and the broad scope of utilization until fire was proved to be one of the greatest forces contributing to the advancement of the race.

Few of us appreciate to what extent our lives are dependent upon combustion, we might say that, just as food is the basis of life, so fuel is the basis of industry. As a matter of fact, our food indirectly depends on fuel, for, without fuel, we would not have the implements to till the soil, nor the means of conveyance to bring the products to our markets.

We are living in an age when the character of our industrial heating processes is fast emerging from the category of an "art" to that of a "science." The average heating process today is no longer dependent upon the traditions of the past and the intuition and general skill of the workmen. The great progress we have made, and are making, is due to scientific control—the development is our research laboratory of scientific control and scientific methods which definitely prescribe the physical and chemical conditions under which we can obtain the highest quality standards of production at the lowest possible cost.

It is not the purpose of this paper to improve heating processes, but rather to drag them down to a practical level. The dramatic side of the steel industry is from the metallurgical point of view. The various treatments have received a vast amount of research, development and publicity, and rightfully so, but no matter how theoretically refined the treatment, the minute it is put into operation on a productive scale, the operating considerations become all important and foremost of these is the application of heat.

The two reasons for considering any new process are: First, because it will produce the highest quality of product, and second, because of its low cost of operation. These same reasons enter into the process of applying the heat which governs the ultimate characteristics of the product and the economy of the operation. The B. T. U. is a most ravenous animal, and unless coralled and fed on useful work, will surely consume vast quantities of the companies' capital.

It has been found that many heating processes did not produce the same desirable results when placed in commercial operation as were obtained in the research laboratory, due chiefly to the inability to control, in the large industrial furnaces, the combustion of fuel in such a way as to definitely regulate at all times the furnace temperature, uniformity of heat application, furnace atmosphere and the other considerations necessary. This lack of control has been primarily due to the great difficulty involved in mastering the technique of efficient combustion and uniform heat application of our solid and liquid fuels.

Here in the United States we have become heir to a land especially favored with valuable supplies of essential raw materials, the most valuable of which is coal. Without coal our present civilization could not continue. With abundant deposits of this valuable substance at our command, we have entered into this field of combustion blindly and in years to come no line of present endeavor will come in for as much criticism as will our fuel consuming practices. Gas is the only constituent of coal which, economically, is available for fuel, and therefore, combustion and fuel utilization from the present or future civilization point of view, means the combustion and utilization of gas obtained from coal.

Gas is the ideal industrial fuel, because the development of its heat energy and the application of that heat can be most accurately controlled. Gas delivered at a furnace is in the proper condition for its immediate development into heat energy.

Considering gas, then, as the industrial fuel, its application necessitates equipment, which is self contained, permitting the fuel to be converted into the most useful form of heat units before it leaves the component parts of the system, which applies these heat units where they are needed.

The prime consideration in the efficient combustion of fuel is the rate of combustion. The more rapid this

combustion can be made to take place the more effective will be the heating. As a result of research into the economy in heat transfer, due to intense combustion, the principle of surface combustion of gaseous fuels was developed, which term refers to the well known influence of light wave energy upon a gaseous mixture to accelerate chemical reaction.

Increasing the temperature of combustion does not necessarily mean an increase in the flue gas temperature. Because of the fact that combustion takes place with no delay, the heat carried by the products of combustion will have the longest possible time to give up heat before leaving the heating chamber. By way of contrast, attention is called to the familiar long flame combustion. In such a case the rate of combustion depends upon the rate at which the air and gas diffuse one into the other, bringing within actual range of one another the molecules which are to react. The products of combustion set free in that portion of the flame near the flue have only a short period to give up their heat, with the result that these gases leave nearly at flame temperature, in fact most of the installations of this type have combustion continuing on into the flues or checkered chambers.

Another important advantage of the rapid combustion is the high temperature of the reaction, and therefore, the greater effectiveness of the radiant heat. Radiant heat is proportional to the fourth power of the obsolete temperature, and is the most effective heat transfer agent known to science. This form of heat is not only the most effective, but also the one most easily applied. These rays can, by proper direction and reflection, be concentrated, or diffused in the same manner as light waves.

The following tabulations are the actual results recorded by the engineers of the respective plants and well illustrate the results obtained in practice by the application of these principles.

On an installation in one of the large steel plants on sheet and pair furnaces, the average of five days' operation, one day including heating furnace from cold, showed a consumption of 1,585 cu. ft. of natural gas per ton of steel heated compared to 3,850 cu. ft. of gas per ton on the former operation. The saving in actual dollars and cents on fuel alone liquidated the initial investment covering the equipment in sixty-seven days' average operation.

In still another steel plant, the application of the surface combustion high pressure system to Merchant Mill furnaces showed a consumption of 3,100 to 3,800 cu. ft. of coke oven gas per gross ton of steel heated under steady operation as contrasted to approximately 7,000 cu. ft. of gas per ton on the former operation. The average steel heated was 10½ tons per hour. Considerable saving on furnace repairs have been reported by the plant officials.

In a wire mill by the application of these principles of combustion it was possible to displace hot producer gas for the various heating operations with city gas. All of the furnaces in this plant consisting of annealing, wire baking, patenting and other heat treatments are now operating on the system, in some cases displacing electric heat treating furnaces. On the patenting furnace a production of 1,200 lbs. per hour at 1800 deg. F. was secured on 1,800 cu. ft. of gas, and produced a much higher quality of product.

It might also be interesting to note a direct comparison of a gas fired heat treating furnace with an electric heat treating furnace, both furnaces being designed for the particular operation. The treatment consisted of continuous hardening of roller bearings. The furnaces being designed to treat 500 lbs. of the rolls per hour. The gas furnace produced 660 lbs. per hour, consuming 1,750 cu. ft. of 290 B. T. U. water gas, which consumption showed a saving of 43½% over the old style furnace previous used. With gas at 42c per 1,000 cu. ft., the cost on the new furnace per lb. of steel treated was .11c for fuel. On the electric furnace, which was built for the same work, the production was only 434 lbs. per hour on a consumption of 71 k.w, which, at 1¾c per k.w., showed a cost of .28c per lb. of steel treated. As a result of economies secured by the application of these principles this plant, which is one of our largest roller bearing plants, has also found it advisable to displace their entire blue water gas plant with city gas.

The highest temperature attained in the combustion of a gaseous fuel, the so-called flame temperature, for any given inlet temperature of the air and gas, depends chiefly upon the quantity of air supplied, the intimacy of the mixtures of air and gas and the amount of heat dissipated during the period of combustion.

To burn a unit volume of gaseous fuel of a definite B. T. U. value requires a definite amount of oxygen, which is obtained from a definite amount of air. Correct proportioning is not only important from the point of view of efficiency, but it is essential for obtaining the desired furnace atmosphere. Equipment which provides for automatic proportioning of air and gas has been one of our greatest needs in the past. Systems to provide for this accurate control have been developed and are now serving in thousands of industrial plants all over the world.

In order to obtain complete combustion of the gas and air it is necessary for them to be intimately mixed. It is of interest in this connection to note that researches by Bairstow & Alexander, in 1905, indicated that mixtures of air and gas could be allowed to stand as long as 17 hours without becoming homogeneous. It is, therefore, necessary to utilize some definite means of positively mixing the air and fuel before combustion occurs. The simplest and most effective type of mixer is the venturi type, in which the expansion of one of the gases causes the absorption of the other.

Combustion zones must be so designed as to favor to the highest degree rapid combustion. Their design is, therefore controlled by two consideration: First, to submit the entering mixture to the highest possible temperature, and second to baffle or retard the velocity of the mixture to the point where combustion will have been completed before leaving this zone. The efficiency or rate of combustion, therefore, is not affected by any missing of these gases after leaving the combustion zones with inert gases which may be present in the furnace chamber.

The realization of the principles, thus far set forth, is entirely dependent upon the equipment and its proper application for heat generation. The following points are of prime importance to insure satisfactory operation of such equipment:

1. Operating characteristics of the equipment:
   (a) Under this consideration it is necessary to appreciate that correct mixtures of air and gas are explosive, and, therefore, require the greatest care in handling.

(b) The automatic proportioning device must have a high mechanical efficiency or, in other words, a wide range of regulation.

(c) The manifold piping, arrangement and size must be so designed to maintain the pressure head built up by the proportioning device.

(d) Construction of the burner must be of a type which will prevent over heating and consequent destruction of the burner tip.

2. Arrangement of the burners:

(a) Burners must be so arranged that equipment on each furnace is easily and simply controlled. Location of the burners depends upon the type of heating operation.

(b) Number and size of the burners depends upon the shape and size of the heating chamber as well as upon the amount and temperature of the work to be treated.

3. Size and shape of combustion chamber:

(a) In determining the size and shape of the combustion chamber of any furnace it is, of course, necessary to design this chamber in proportion to the amount of fuel to be consumed as determined by the amount of work to be treated. Through information gained from practice and research a definite and working ratio has been established between the cubic feet of gas consumed per hour and the square feet of internal heating surface for all types of furnaces.

The very nature of the combustion of fuel tells us that the burned gases must leave the heating chamber at as high a temperature as the temperature of the chamber itself and in some cases these flue gases carry away as much as 60 per cent of our total heat. We have, however, a means of utilizing this heat by application of recuperators or regenerators. We find regeneration installed on many of our large industrial furnaces, such as open hearth and glass melting furnaces, but we must bear in mind that regenerators were not installed on these furnaces because of the desire to save fuel primarily, but were considered necessary in attaining the high operating temperature.

Up to the present time only a very limited number of recuperator installations have been made. We are just at the beginning of this development, but from now on we should see a very rapid growth in the application of this form of economy equipment to many heating operations. There are several furnace companies today that are manufacturing equipment of this kind, using both refractory recuperators and metallic recuperators. These various equipments, generally speaking, represent a distinct advancement in the art.

And all this only makes us realize that the gas practices of tomorrow will bear little resemblance of those being used at the present time. Could we but visualize into the future, we might see that tomorrow will be a day of giant power zone plants. Domestic heating will be accomplished through the use of gas. Such railroads as are not electrified will use coke or powdered fuel for steam locomotion. Gas will be substituted for oil, coal and electricity in industrial furnaces. In no place and under no circumstances will solid fuel be burned raw to provide power or heat. Such transformation in our fuel practices necessitates the carrying on of extensive reasearch and experimentation. The demand of the moment is for engineers and executives having inquisitive minds that refuse to submit to the tyranny of custom. As one has said, "Engineering is a combination of brains and materials—the more brains the less the material. All of the complex calculations in the world mean nothing if the calculator has not a sound understanding of the relationships which enter into the hypothesis. Without this understanding, a mathematical calculation is just like a trip through a railroad tunnel; you have gone in some place and have come out some place, but you don't know how you got there or where you have been."

DISCUSSION

J. E. Harrell: I would lik to ask Mr. Evans if the automatic proportioning feature can be used on both high and low pressure systems?

F. J. Evans: We install both systems and the automatic proportioning feature applies both to the high and low pressure systems. In the high pressure system the gas is compressed as high as 15 lbs. at the burner. In the low pressure system, the gas has a pressure of three to four inches of water and air at a pound, and the air entrains the gas so that you have perfect proportioning. The high pressure system is used more and more because of its simplicity in piping.

H. C. Bratton: What is the difference between burner pressure for the two systems?

F. J. Evans: On the low pressure systems using coke oven gas you have a pressure of 3½ to 4 inches at the burner. In the high pressure system you have a pressure of about 6 to 8 lbs. at the burner.

J. M. Hawk: I would like to ask Mr. Evans if there is any serious competition between the electric heated and gas fired furnaces? He spoke about the fuel cost of a gas fired furnace being one-half that of an electric furnace. Itsn't there any other consideration than cost, such as scale formation?

F. J. Evans: There is room for lengthy controversy on that subject. In the particular instance given, the cost of current was one and three-quarter cents per kilowatt hour. The matter of product is quite important. The average electric furnace used for heat treatment must contain air or some gas, and if there is air, metallic oxide or scale is being formed. In the gas furnace, the gas can be maintained slightly reducing and the furnace operated with .02 or .03 water pressure, so that any leak will be outside and not cause scale formation.

Also, the gas furnace can be absolutely automatically controlled just as satisfactorily as can the electric furnace.

J. M. Hawk: What is the possibility of an automatic proportioning device for large heating units like blast furnace stoves?

F. J. Evans: The large burners shown on the screen as being used for boiler firing with blast furnace gas should, with slight changes, be satisfactory for blast furnace stoves. I am not familiar enough with that type to talk intelligently on it, but our company feels that that type of equipment can be applied to blast furnace stoves.

THE RELATION BETWEEN TECHNICAL PAPERS AND THE LIFE AND WORK OF OUR ASSOCIATION.

(Continued from Page III.)

operated under varying conditions which will continue to give rise to papers dealing with operation and possibly to some extent with actual economics resulting from new and improved methods.

Another subject of now established importance and one which our Association has always sponsored but which did not come into its present development until 1910 is Safety in Industry, the conservation of human life and health. This subject has since been very frequently discussed in individual papers and with the adoption of the Committee system in 1916 Safety has always been considered by a Committee whose annual reports have replaced the individual papers.

Reference to Committees for research and report has been the solution of many problems of a recurring or developing nature such as standardization, motors, bearings, education, electric furnaces, illumination, etc. Standing committee consideration is, we feel, the ultimate answer to the question of handling more or less routine subjects which must be continually brought up to date in order to keep abreast of developments in the art.

In general, by tracing the ascendency and decline of various subjects dealt with in our papers, we find new developments coming in at intervals to claim our attention superseding the older and more settled subjects once of a controversial nature.

New subjects will be brought forward from time to time and will naturally be subjected to the investigating eyes of engineers who will analyze, describe, and approve or condemn through the medium of papers which will be the ultimate written record in our files to which the engineering profession, seeking technical information, may turn with every confidence. As this reference value is established our publications will grow in prestige and usefulness thus increasing their value as advertising media through which manufacturers can reach the discerning readers with purchasing power.

All of these phases combine to constitute a successful engineering publication. The future then of our Association and its official organ depends on the quality of the material we can obtain in the form of papers or reports before our various Sections or before the Association assembled in Convention.

Turning from the papers of the past and looking into the future what is to shape the course of our activities so that we as an Association made up of various Sections and ultimately of individuals, may advance steadily along the economically most valuable lines of approved modern practice? If we could look back to our own age from some time in the future we would consider our present practices as wasteful; but I think we would also mark the present as the period of real awakening of engineers to the problems of conservation of all resources, especially those natural resources with which our Country has been so richly endowed. Those formerly considered limitless, we now realize to be limited by waste and rapidly increasing in demand to the point where efficient use becomes our imperative duty.

These resources hitherto freely used and often ruthlessly abused, are approaching exhaustion within measurable time, so that not only remote posterity, but our own children will certainly suffer unless Engineers determine methods and adopt practices to avoid waste through efficient use and intelligent conservation.

Our Association through the investigations of its Fuel Saving Conferences will be able to publish reports looking toward the elimination of wastes and the more economical use of labor and materials. These reports will eventually establish our published records on a plane where they will serve all the Engineering professions as authentic records of careful investigation and sound thought.

The Committee scheme of investigation naturally lends itself to this phase of our work; and is, we feel, most desirable for several reasons. First, we then benefit by the combined thought of several investigators rather than by the possibly biased opinion of one. Second, because the actual labor of research and investigation can be divided so as not to be so burdensome for any one as to interfere either with his normal work or with the thoroughness of his thought on the subject assigned to him.

As I have gathered the opinions of many of our Members the feeling in favor of the Committee system seems to be steadily growing. As regards the papers and activities of the Sections there will always be an opportunity for the presentation of individual papers; and yet we feel that even in Section activities, the Committee system can be made to function to advantage.

There are some who feel that our papers might with possible advantage, branch into the fields of Plant management and finance; but the wisdom of this is questionable. As soon as we go beyond the sphere in which we are recognized, not only will individual papers lack weight but our papers on subjects in which we are competent will be correspondingly less highly regarded.

By way of a summary then, lt us look toward the realization of the following objectives:—

1st. More short papers by members for Section meetings each meeting to be devoted to one general line of thought. It may then be possible to have the several papers digested, complied into a major paper of real value to our Association and finally published.

2nd. The gradual but limited use of Committee papers and reports in Section work not conflicting, but in line with the work of the major committees of the Association.

3. The development by our National Association of the conference idea, to be carried into the field of one Section or another in order to strengthen and stimulate interest in and through the local Section.

4th. A more careful check-up of papers published in our proceedings in order to raise still higher the reliability of our record as to data and facts.

5th. Each member should feel himself responsible for the advancement of his Section, and through it for the advancement of the aims and work of our National Association. To this end each member must give of his time and effort and must realize that he owes to his fellow member an effort to overcome the mental inertia, fear, or whatever may stand between him and the free expression of his views in papers or discussions. These papers and discussions are needed to maintain and add to the already widely recognized value of our Monthly and annual publications, as the authentic written record of our Members' experiences.

Your motor horses—

are they big ones or little ones?

Wagner Products

MOTORS
Split-phase—Induction
Repulsion—Induction
Pow-R-full Squirrel-cage
Pow-R-full Starterless
Slip-ring Induction
Fynn-Weichsel

TRANSFORMERS
Distribution
Power

FANS
Desk, Wall and
Ceiling Types
AC and DC

AUTOMOTIVE
Starting—Lighting
Ignition

Official service representatives for Lockheed four-wheel hydraulic brakes

1220-2

YOU are interested in motors for the sake of the work you get out of them. Off-hand you would say (wouldn't you?) that you ought to get as much work out of one 15 hp. motor as another 15 hp. motor.

But you would be wrong.

A 15 hp. motor is a motor guaranteed to carry a 15 hp. load *continuously* with no more than 40° rise in temperature.

But the amount of work you get out of a motor depends upon *six* points, of which the rated horsepower is only one, and often not by any means the most important one. The other five are:

1. The amount of load it can start without blowing the fuses.
2. The size of the overload it can carry momentarily without stalling, burning out or blowing the fuses.
3. The amount of magnetizing current it demands.
4. The effect it has on voltage, and hence on the performance of the other motors in your shop.
5. Its ability to hold its speed under unfavorable conditions.

You can buy motors that don't cost much in terms of rated horsepower, but *will they do the work?*

The FYNN-WEICHSEL MOTOR costs more per rated horsepower, but it gives you more motor—more work—for your money.

WAGNER ELECTRIC CORPORATION
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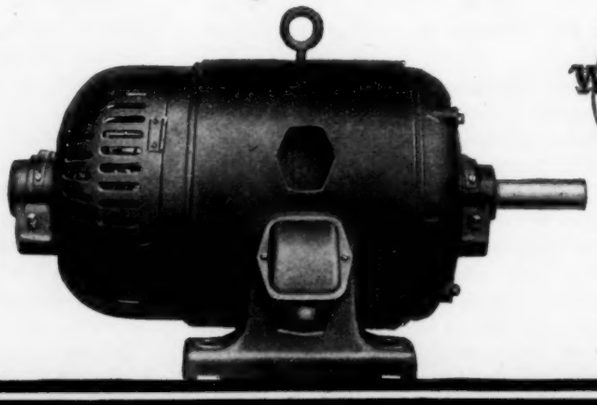

Fynn-Weichsel

The motor that corrects power-factor

ADVERTISING PAGES REMOVED

Among The Manufacturers

The D. Connelly Boiler Company, of Cleveland, O., has been awarded a contract for two 1287 H.P. boilers for the Ohio Works of the Carnegie Steel Company. This is a repeat order, making a total of six 1287 H.P. Connelly units at this plant. These boilers will make steam for the new Turbo Generators now being installed to furnish power for the MacDonald bar mill extensions.

The Mesta Machine Co., Pittsburgh, Pa., has issued a bulletin which describes Mesta Automatic Plate Valves. This bulletin is known as Bulletin "D." It contains a great deal of interesting data; also curves showing temperature of air delivered by compressors and blowing engines; also factor curves for flow of gasses through orifices and nozzles. This bulletin can be obtained by writing L. R. Brown, Publicity Dept., Mesta Machine Co., Pittsburgh, Pa.

The Westinghouse Electric and Manufacturing Co. announces the sales of the following equipment:

Youngstown Sheet & Tube Co.—Seamless tube mill drive—3000 H.P., 600-volt D. C. 30-100 r.p.m. D.C. motor; 3000 H.P., 600-volt, 125-200 r.p.m. D.C. motor; 3—650 H.P., 225-400 r.p.m., 600-volt D.C. motors; two 3000 K.W. motor generator sets.

National Tube Co., Ellwood City, Pa.—Tube mill drive—1 1800 H.P. wound rotor induction motor; 252 r.p.m., 2200-volt, 3-phase, 60-cycle.

Acme Steel Goods Co., Riverdale, Ill.—20-inch—16-inch hot strip mill drive—1500 H.P., 705 r.p.m., 2200-volt, 3-phase, 60-cycle, wound rotor induction motor; 1500 H.P., 200-400 r.p.m., 600-volt D.C. motor; 3—1800 H.P., 185-370 r.p.m., 600-volt D.C. motors; two 1800 H.P., 125-250 r.p.m., 600-volt D.C. motors; two 2000 K.W. motors generator sets.

Phoenix Iron Co., Phoenixville, Pa.—36-inch blooming mill drive—3500 H.P., 0-120 r.p.m. reversing mill equipment, with 3,000 K.W. flywheel, motor generator set.

Bethlehem Steel Co., Lackawanna, N. Y.—One 1000 K.W. motor generator set, with automatic switching equipment.

The Delta Star Electric Company has issued a new bulletin covering standardized sub-stations. This bulletin is known as No. 12 and describes a new line of standardized steel tower outdoor sub-stations intended for installation by utilities serving or customer's buying, power from high tension distribution lines.

The Electric Controller and Manufacturing Company has just announced a new push button operated oil switch for starting squirrel cage induction motors directly across the line.

This device is known as the Type ZO Starting Switch and is controlled from one or more push button stations, which may be located at convenient points. The starting switch is provided with four pairs of heavy contact fingers, three of which handle the main line in the case of three phase or two phase three-wire motors, and the fourth pair handles the control circuit to the push button when the switch is arranged for no-voltage protection. In the case of two-phase four-wire switches all four lines are disconnected in the "off" position, when the switch is wired for no-voltage release. When wired for no-voltage protection one line runs direct to the motor.

The Type ZO Starting Switch uses a very accurate inverse time element temperature overload device, which consists of 2-alloy wires each, attached at one end to an adjusting screw, and at the other end to a multiplying lever which operates a quick make and break contact. The wire is connected across the secondary of a small current transformer. The gauge of the expansion wire and the winding of the secondary of the transformer remains the same, regardless of the horsepower ratings or voltage of the switch, and the size of wire and number of turns of the primary is proportioned to suit the rating of the motor. An increase in current or an overload on the motor produces an increase in the current flowing in the secondary circuit, which causes the expansion wires to lengthen and, if the overload is severe enough or is of sufficient duration, the wires lengthen sufficiently to trip the overload relay contacts, causing the starting switch to open and disconnecting the motor from the line. The wires then cool and the overload relay contact automatically resets if a switch is wired for no-voltage protection. A hand reset of the overload device by means of a small button projecting through the case is provided on switches arranged for no-voltage release.

The overload device protects the motor against injury due to phase failure. If an attempt is made to start the motor with one phase open, the switch will open in less than five seconds, and the manufacturer states that it is impossible to burn out a motor due to phase failure or overloading when protected by this starting switch.

The oil tank is drawn from a single piece of sheet steel and cannot leak oil. The tank latches are arranged so that the tank can be lowered and left suspended to catch oil dripping from the contacts while the switch is being inspected.

On account of creepage of oil due to capillary attraction and from a slight splashing when the magnet surfaces engage, all moving parts of the switch are kept lubricated, which protects the switch from corrosion when installed in corrosive atmospheres.

Type ZO Switch is arranged for conduit connection and is of compact dimensions, 13 inches high by 9 inches wide.

The P&H family of excavators has recently been enlarged by the development of a new ½ yard, full revolving gasoline or electric machine, mounted on Corduroy Traction and known as Model 204.

This new machine, which is designed and built by the Harnischfeger Corporation, Milwaukee, Wis., resembles the other P&H. models in that it involves the same general principles of construction and operation as has long been recognized as a standard in the gasoline-driven excavator field.

The power is supplied by a single gasoline motor, of the heavy duty, tractor type, developing 40 H.P. at 960 r.p.m. All power is transmitted through cut steel gears with the minimum number of reductions. The two main drums are independently mounted on separate shafts and are controlled by outside

band clutches and brakes, the clutches being operated by power clutch control. The drums have a standard line speed of 110 feet per minute, but may be lagged to give higher speeds for certain work. Both the revolving frame and car body frame are of cast steel, in one piece. All shafts are turned and ground to micrometer size and all bearings are provided with Alemite or pressure cup lubrication. The Corduroy frames are heavy steel castings, which receive the weight of the machine from two heavy forged axles. The treads are non-cloggable and the tread rollers are swiveled in two directions to adjust to any irregularities of the ground. All gears are well guarded to protect the operator, and the first reduction and travel gears are fully enclosed, running in oil. There are two travel speeds—11/16 and 1⅜ M.P.H.—forward and reverse. All steering is controlled from the operator's platform by use of a simple hand wheel. The main machinery and operator's platform are fully enclosed in an all-steel cab, provided with suitable doors and windows for care and operation.

This machine handles a ½ yard dragline or clamshell bucket, on a 30-foot boom and has a rated lifting capacity of 13,000 pounds, at 10-foot radius, which is 75 per cent of its tipping capacity. The shovel is ½ yard capacity and of the standard P&H design, with an all-steel, box section boom, outside dipper sticks and a crowding motion which enables the operator to have full control of the dipper at all points, acting independently from the hoisting motion.

This machine meets a distinct need for a lightweight, sturdy, fast, powerful and durable machine possessing great mobility and ease of control.

A new device for limiting the extent of upward travel of the hook on an electric crane operated by direct-current motors has been brought out by The Cutler-Hammer Mfg. Co., Milwaukee. It has a number of features which insure positive action and add to the safety of the hoisting operation.

When the hoist block reaches the upper limit, it raises a counter-balance weight and allows a weighted lever to drop, thus tripping the contactors. The latter disconnects the motor from the line and connects a resistor in the armature circuit of the motor, which then acts as a self-excited series generator and gives dynamic braking. Quick, accurate stops are obtained because the braking effort is independent of line conditions and of the position of the motor controller, and is proportional to the speed of the motor. Taps are provided on the resistor to adjust the dynamic braking effort in accordance with service conditions.

When the limit switch is in the "tripped" position, a bypass circuit makes it possible, on reversing the controller, to lower the hoist block out of the limit position, and the counter-balance weight automatically resets the contactors. Arrangement can be made for manual or rope-operated reset instead of automatic reset, if necessary.

The switch can be mounted in any one of four different positions, and is made in two sizes, one for 40 H.P., 115 volts; 80 H.P., 230 volts; and 100 H.P., 550 volts, and the other for 75 H.P., 115 volts; 150 H.P., 230 volts, and 200 H.P., 550 volts. It can also be used with an alternating-current motor, in which case two of the conductors are disconnected to stop the motor, but no braking effect is obtained, and minor changes in the limit switch and the controller are required for lowering the hoist block out of the limit position.

One of the most radical change-overs from steam to electric drive in the history of the steel industry is to be made by the Colorado Fuel and Iron Company at its Minnequa Works, Pueblo, Col. This plant, the largest steel mill in the West, recently completed arrangements for the adoption of electric power, generated on the premises, for use in its rolling mills.

The decision to electrify was reached about a year ago, when the Colorado Fuel & Iron Co., executives decided that electricity would prove more economical and efficient for the operation of their rolling mills. The mills are, at present, engine-driven, using low pressure steam obtained from a hand-fired boiler plant. This plant will be superseded by a complete new power house, using powdered fuel and waste gas fired boilers, which will provide steam at 300 pounds pressure and 180° F. superheat.

Complete electrical equipment will be furnished by the General Electric Company. Two 10,000-kilowatt turbine generators will be the prime movers, and will furnish alternating current to the main power lines at 6600 volts. Other power house equipment will consist of one 150-kilowatt, turbine-driven exciter and one motor-driven exciter unit. Two 1,000-kilowatt synchronous motor generators will furnish direct current for operating power house auxiliaries and will tie in with other direct-current mill power circuits. Two 200-kilowatt, dual generators, driven either by steam turbines or by induction motors, will be used to start the station auxiliaries in the event of failure of power from other sources. Three single-phase reactors will limit the short-circuit currents on the auxiliary alternating current bus. A complete switchboard will also be installed in the power house.

Complete electrical equipment will be furnished for driving a rod mill, a 10-inch merchant mill, a 14-inch merchant mill and a rail mill. The rod mill has 18 stands of rolls. The first six stands will be driven by a 3,000-horsepower motor; the seventh stand by a 1000-horsepower motor; the eighth and ninth stands, by a 1,000-horsepower motor; stands Nos. 10 to 15, inclusive, by a 3,000-horsepower motor, and the remaining stands will be driven by a 1,500-horsepower motor. The 3,000-horsepower motors will run at a speed of 450 r.p.m.; the 1,000-horsepower motors, at a speed of 720 r.p.m., and the 1,500-horsepower machine will be rated 450/550 r.p.m. Both the 3,000 and the 1,000-horsepower units will be alternating current machines, while the 1,500-horsepower motor will use direct current furnished by a 1,600-kilowatt synchronous converter, the power for the converter being stepped down from the main lines by a 1,680-kv-a transformer.

Each mill will be equipped with a switchboard and necessary control. The 10-inch merchant mill will be driven by two direct-current motors, both of which will be direct connected. Direct current for these machines will be furnished by a 1,600-kilowatt synchronous converter with a 1,680-kv-a transformer for stepping down the voltage from the main power lines. One 300-horsepower 200/300 r.p m. motor will drive a single stand of 14-inch rolls and a 1,500-horsepower, 200/300 r.p.m. motor will drive six stands of 10-inch rolls.

Two direct-current motors will drive the 14-inch merchant mill. As in the case of the 10-inch mill, the power from the main line will be stepped down by a 1,680-kv-a transformer and will then be changed to direct current by a 1,600-kilowatt converter. One 1,500-horsepower, 100/150 r.p.m. motor will be direct connected to stands Nos. 5 and 6, an will drive the first four stands through a rope transmission. A 750-horsepower, 150/250 r.p.m. motor will drive stands Nos. 7 and 9, inclusive.

The roughing stand of the rail mill will be driven by a 2,000-horsepower, 450 r.p.m. induction motor, a 3,000-horsepower induction motor of the same speed will drive the intermediate stand, and a 1,200-horsepower, 450 r.p.m. induction motor will drive the finishing stand, each motor being geared to the mill through the usual double herringbone reducing gear.

The Electric Illuminating Company of Boston, for their Weymouth plant, have purchased from the Westinghouse Electric and Manufacturing Company the largest self-cooled transformers ever built. These transformers consist of a two 25,000 kv-a, three-phase, self-cooled, 60-cycle transformers, stepping up from 14,000 volts to 120,000 volts.

This investment in equipment is part of their order for over one-half million dollars worth of equipment, awarded to Westinghouse, to be used for a tie-in between the new Boston Edison plant, at Weymouth and the Montaup Electric Company, at Fall River. Eventually the tie will connect with the New England Power Company at Millbury and Davis Bridge.

In this new installation, are also included 19 132 kv, 400 ampere, single throw, electrically operated oil circuit breakers, complete with electric mechanism mechanically trip free in all positions. Each breaker is equipped with six-bushing type current transformers for operation of instruments and relays. The interrupting capacity of these breakers is one and a half million Kv-a at 132 kv.

For the substations they are installing two 15,000 kv-a transformers and one 5,000 kv-a with similar characterisitcs as the large transformers. All of the transformers are so designed that auxiliary apparatus can be applied later to make them suitable for tap changing under load.

The advance in the art of coil making is reflected in the improved Segur Armature Coil Spreader, which has just been placed on the market by the Electric Service Supplies Co. The improvements in the coil blocks, the end supporting knuckles and the accuracy with which the machine duplicates the angular relation of the slot portion of the coil, all commend themselves to the user at first sight.

This device embodies the latest idea in coil forming equipment in a strong, compact and readily adjustable machine, capable of producing better coils, at less cost than any similar device the market affords. The setting-up time has been reduced materially by the simplicity of its parts and their arrangement. Actual costs indicate that the spreading of coils can be accomplished more economically with this spreader than any other similar machine.

The lever operated, end supporting knuckles, do away with loose parts, such as bolts, pins, toggles, etc., and is undoubtedly the speediest and most efficient holding device perfected to date. With its adjustable side plates of fibre, readily renewable when necessary, the advantages of this support are clearly seen, and its locking feature is simple, rugged and positive in action.

The spreading of loops always requires the holding of the slot portion of the coil firmly on four sides. This is accomplished by an unique coil block which is adjustable both for the height and width of the coil, and is made entirely of steel, properly case hardened at wearing points. This construction gives the maximum of useful life and does not give way as aluminum or bronze coil blocks usually do.

The rapid, snappy action of the coil block is further carried out when it is realized that one movement of a single arm controls both coil blocks either front or back, cutting down the operations to one, as compared with four operations in the ordinary types of such apparatus.

The holding ability of the coil blocks is absolutely within the operator's control at all times, and is so arranged that loops can be spread before varnishing, although this method is not recommended. The best authorities on coil making invariably suggest that loops be varnished and baked before spreading. This process toughens the cotton or silk insulation and its advantages are obvious.

Many other advantages are embodied in this device, and when used with the improved Segur Loop Winder, offers to the coil maker a very complete and compact coil forming device, adjustable for practically any standard type of coil. The coil, a taken from this spreader, can be completed with a minimum of hand operations, and can be made to equal the best form wound coils the market affords being limited only by the time and knowledge of the operator.

The Sharples Specialty Company of Philadelphia advises that a new Pacific Coast office has been opened at 688 Howard street, San Francisco, under the name of The Sharples Specialty Company of California. Mr. L. A. Taylor, who is well known among the coast industries, especially for his wide experience with the applications of Sharples Super Centrifugal Force, will be in charge of the San Francisco and the Pacific Coast territory.

STATEMENT OF OWNERSHIP, MANAGEMENT, ETC., OF

IRON AND STEEL ENGINEER

(Required by Act of Congress of August 24, 1912)

Name of Publication: Iron and Steel Engineer, published monthly at Pittsburgh, Pa. (Report of March, 1925.)

Editor—John F. Kelly, 706 Empire Bldg., Pittsburgh, Pa.

Business Manager—John F. Kelly, 706 Empire Bldg., Pittsburgh, Pa.

Names and addresses of stockholders holding 1 per cent or more of total amount of stock: None.

Board of Directors

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G. H. Schaeffer, First Vice Pres., Carpenter Steel Co., Reading, Pa.
S. S. Wales, Second Vice Pres., Carnegie Steel Co., Pittsburgh, Pa.
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Known bondholders, mortgagees and other security holders, holding per cent or more of total amount of bonds, mortgages or other securities: None.

JOHN F. KELLY, Editor and Business Mgr.

Sworn to and subscribed before me this 28th day of February, 1925.

JOHN G. HOSICK, Notary Public.

(My commission expires March 7, 1925.)

The Timken Roller Bearing Company, of Canton, Ohio, announces with deep regret, the retirement of Heman Ely, Vice President and Treasurer, from active connection with the company. Mr. Ely became associated with the Timken Company in 1909 as Secretary, and in 1916 was also appointed Treasurer. He became Vice President and Treasurer in 1920.

Mr. Ely's retirement closes a sixteen-year association with the Timken Company. Beyond the statement that he will take a short vacation, Mr. Ely announces no plans for the future.

The Roller-Smith Company, 233 Broadway, New York, N. Y., announces the appointment of the Detweiler-Bell Company, 101 Milk street, Boston, Mass., and 152 Temple street, New Haven, Conn., as its representative in the states of Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island. Having offices both in Boston and New Haven, the Detweiler-Bell Company is in an excellent position to handle the Roller-Smith Company's line of electrical measuring instruments and circuit breakers in the entire New England territory.

New Readers of the Iron & Steel Engineer

L. C. WILSON,
Republic Flow Meters Co.,
617 Engineers Bldg.,
Cleveland, Ohio.

I. A. NICHOLAS,
Spec. Engr., Carnegie Steel Co.,
Clairton, Pa.

G. TAYLOR SWARTS,
Vice Pres., Steam Equipment Mfg. Co.,
8077 Jenkins Arcade Bldg.,
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ALBERT C. CULBERTSON,
Manager, Chapman Stein Furnace Co.,
Mt. Vernon, Ohio.

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Steam Engr., Bethlehem Steel Co.,
Sparrows Point, Md.

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Electric Superintendent,
Jones & Laughlin Steel Corp.
S. S. Works, Pittsburgh, Pa.

E. H. WILSON,
Sales Engineer,
Motors, Control & Accessories,
Robbins Electric Co.,
Liberty Ave., Pittsburgh, Pa.

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E. P. DUNMIRE,
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Erie Malleable Iron Co.,
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